Physical Examination

and

Diagnostic Anatomy

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PREFACE

This book, as its title implies, is intended to be a text-book on Physical *Examination*, its technic, fundamental methods and principles, to prepare the students for the study of any of the various able and comprehensive works already written upon Physical *Diagnosis*.

The diagnosis of specific disease conditions has been carefully avoided, as this work deals chiefly with the normal subject, a few instances of the abnormal being mentioned here and there to emphasize the importance of certain procedures and to retain the interest of the student.

The subject matter has been arranged to accord with what I believe to be the natural course that an average minded student pursues in acquiring knowledge regarding any subject which attracts spontaneous interest.

My experience in the teaching of Physical Diagnosis has convinced me that the student's initial course in this work should be chiefly practical, with a minimum of text-book study. This book is intended to supply that text, and at the same time avoid placing before the student exhaustive discussions and problems of diagnosis which he is not prepared to fully understand at

this stage of his education. In other words, it has been my object herein not to divert the attention from the fundamental and essential primary principles of the subject. The illustrations used herein (excepting photographs) were drawn by the writer, some are based upon his own investigations and some upon well-established anatomical relations. It will be noted that each illustration contains only those lines which are absolutely needed to present the subject matter, excluding from the picture all features that might divert the attention. I am aware that some important facts and illustrations are repeated occasionally throughout this work, but this is done in order that they may be fixed more securely in the student's mind, and from more than one point of view.

It is expected that the instructor will augment much of the matter contained herein by remarks appropriate to the cases he has before the class.

I wish to express my indebtedness for advice from my friends Professor Hermann M. Biggs, Professor William Elser and Dr. Bolduan, and Dr. McSweeney and Dr. Aikman for help in the preparation of photographs.

CHARLES B. SLADE.

NEW YORK CITY.

CONTENTS

SECTION I

SECTION II

SECTION III

SECTION IV

SECTION V

SECTION VI

SECTION VII

SECTION VIII

SECTION IX

SECTION X

SECTION XI

SECTION XII

PHYSICAL EXAMINATION AND DIAGNOSTIC ANATOMY.

SECTION I.

INTRODUCTION AND GENERAL RULES GOVERNING INSPECTION.

INTRODUCTION.

Physical examination (sometimes called *physical exploration*) is the process of determining the gross anatomical condition and relations of the various parts and organs of the body by physical methods.

Physical diagnosis is the detection of departures from the normal by physical examination.

"*Normal.*"—You must understand that in medical nomenclature the word "*normal*" is a negative term with a wide range of application. In physical examination we call that subject, or organ, normal in which we fail to discover any definite signs of disease, deformity, or anomaly. The term "*negative*" is frequently used with the same meaning.

Methods.—The fundamental methods employed in physical examination are INSPECTION, PALPATION, PERCUSSION, and AUSCULTATION. Olfaction

is an aid to the diagnosis of some diseases. Special instruments, appliances, and methods employed are only complex ways of applying the above-mentioned fundamental methods.

System is essential if physical examination is to yield the best possible results. You should at once acquire the habit of employing inspection, palpation, percussion, and auscultation *in the order named*—completing each method, as far as it is possible, before the succeeding one is begun. Furthermore, you should examine every subject in the same systematic anatomical order (see General Rules Governing Inspection—Order of Inspection).

The Examiner.—At no time in the performance of a physical examination should you allow your body or limbs to assume an awkward or uncomfortable position. A strained attitude interferes with acute perception.

The room should be free from noise or other sources of distraction, of a comfortable temperature, and well lighted.

The Subject.—The parts examined should be freely exposed, or as freely as propriety and expediency will permit. Whether standing, sitting, or lying down, the body should rest equally, the arms straight and passive by the sides. The surface examined should face the greatest source of light.

Note.—There are special positions and arrangements of light necessary for some parts of physical examination which will be described hereafter.

GENERAL RULES GOVERNING INSPECTION.

Inspection is using the sense of sight in physical examination.

Inspection should begin as soon as the subject enters your presence. It should be completed, as far as possible, before palpation is begun, but intelligent inspection should continue uninterruptedly throughout all methods that follow it.

There is no method of physical examination which will yield more valuable information than inspection, if it is applied with concentrated care in systematic order and with thoroughness.

The value and amount of information obtainable by inspection grows steadily with the experience and knowledge of the examiner. There is no fixed limit to the valuable results this method may yield, and it is frequently the capable employment of inspection by a talented physician which places him above his fellows in accuracy of diagnosis. The results obtainable by palpation, percussion, and auscultation have more or less definite limits, to which many may reach, and beyond which none can go; whereas the value of inspection is only limited by the knowledge, experience, and skill of the individual who employs it. The power to correctly interpret what is seen may be improved in all by careful study and observation, although some are sure to possess this power to a greater degree than their fellows through natural talent. It is usually

this, the capacity to correctly interpret by inspection, highly developed, which is the chief reason for some physicians' possessing what has been called a strong diagnostic intuition.

Always compare corresponding parts, on the right and left sides, for there is no fixed standard of the normal body, either in contour, proportions, size, or color.

ORDER OF INSPECTION.

To avoid oversight, your inspection should proceed in the following order:

1. **Artificial Aids to Posture or Progression.**—The subject who walks into your presence by the aid of a stick or crutch may have locomotor ataxia, hip-joint disease, or some other disturbance of nervous, osseous, or muscular system. You should note carefully the extent and exact nature of assistance he receives from such artificial aid to progression. The presence of any brace to back, neck, or limbs should receive your careful scrutiny to determine the cause of its use.

2. **General Bearing and Attitude.**—The general bearing may indicate bodily health and vigor on the one hand, or bodily weakness indicative of some recent or present depleting illness on the other. It is also characteristic in many mental diseases. The subject may be well nourished, extremely fat, or emaciated; note the condition he presents.

The attitude is of great importance and should

be closely observed as it not infrequently suggests the presence of a specific disturbance which your further examination reveals. For instance, occasionally the first indication of an acute pleurisy will be the fact that the subject keeps his hand pressed against one side and persistently leans toward that side. Furthermore, the subject who remains sitting when you enter his presence or who is brought before you in a roller-chair and whose face and other attitudes, on close inspection, suggest no other special ailment, is apt to have paraplegia, neuritis, or some disease or disturbance of his lower extremities.

(3) **The gait** is of great significance and often absolutely diagnostic in diseases of the nervous system; for instance, the ataxic heel gait of locomotor ataxia, where the subject is apt to keep his gaze fixed upon his feet while walking. Many other types of gait exist which are diagnostic of special disease conditions.

(4) **The speech*** is also of great importance. Besides being of help in the diagnosis of many nervous diseases and deformities of the upper air passages and mouth, it may lead us to the diagnosis of laryngitis by hoarseness or hypertrophied adenoid growth in the naso-pharynx by a so-called nasal tone.

* The action of some of the muscles of speech is noted by inspection, so that although it does not belong entirely under the head of inspection, it is mentioned here because it should be noted at this stage of physical examination.

(5) **Head (Cranium).**—(1) *Hair.*—Note whether the hair is normally glistening and lifelike, or lustreless, like dried fine fibre, as is often seen following any general disease which depletes the whole system; whether the color is normal for the subject's age or prematurely gray. If the hair is white in isolated spots, with sharp lines of demarcation, not symmetrically placed, it is strongly suggestive of previous alopecia areata, ringworm, or syphilis.

Note the absence or presence of sores or scars, their character and position if present. A healed lesion of the scalp may be the first sign observed which leads us to a correct diagnosis of the cause of serious disturbances in brain function or of tetanus or other infections. If sores are observed, determine whether due to accidental injury, vermin (the vermin may be seen), or to general disease.

(2) *The contour of the head (cranium)* may be changed by congenital deformities of the bones, by the accumulation of an abnormal quantity of fluid in the ventricles (hydrocephalus when the cranium is large and rounded, forehead abnormally prominent, and fontanels open beyond the normal time for their closure), or by injury or disease of bone or soft parts; for instance, syphilitic gumma or sarcoma may form beneath the scalp in the bone or soft tissues. An abscess beneath the scalp will change the contour of the head. Remember that a prominent change in the contour of the face or the neck near the head may give a false impression of

change in the contour of the head itself. In such cases a careful examination of the cranium, while the face and neck are covered with a cloth, will give unbiassed results.

(6) **The Face.**—Careful inspection of the face may give so many valuable signs of various disease conditions that it is only possible to mention a few here. For instance, the *expression*, besides being absolutely diagnostic of some mental diseases, is an aid to the diagnoses of many other conditions, such as the expression of pain, which is familiar to all; the listless expression of typhoid fever; the pinched features of cholera and cholera morbus; the anxious, expectant expression of pneumonia; the dull expression of chronic nasal obstruction, and many others.

The color and condition of the skin—waxy and puffy in some cases of nephritis, sallow and wrinkled in chronic liver disease, and jaundiced where the flow of bile is obstructed; cyanosed (especially on the lips, nose, and ears) in cardiac or respiratory diseases—is of great importance in the diagnosis of many other diseases which the scope of this work excludes. Muscle tonicity: note if the wrinkles in the face are equal on the two sides or if they are more or less absent on one side, as in Bell's palsy or hemiplegia of central origin.

The ears may show tophi (small, yellowish-white lumps) between the skin and cartilage in gout. The ears may be deformed by past frost-bite, or injury, cyanosed as mentioned, or abnor-

mally pale in anæmia. They are abnormally small or deformed in some subjects who are of abnormal mind.

The Eyes.—Among the numerous signs of disease revealed by inspection of *the eyes*, we need only mention a few: *i.e.*, the prominence of the eye-balls in Graves' disease; the unequal, abnormally contracted or dilated *pupils* of cerebral disturbances, syphilis or aortic aneurism; yellowness of the *sclerotics*, which shows so early in jaundice; the pallor of the *conjunctiva* in anæmia; and strabismus, due either to local disturbance of the motor oculi *muscles* or to central nervous disease or accident.

The tongue often bears evidence of present or past syphilis by mucous patches or scars along its margin. By the degree and character of coating upon its surface we are aided in diagnosing certain gastric disturbances, though a slight coating, especially when confined to the posterior portion of the tongue, does not necessarily indicate digestive disturbance, nor does a clean tongue exclude it. Hyperacidity may be associated with a very clean tongue. The position of the tongue when protruded is often of importance in diagnosing a nervous disease. In hemiplegia it is turned toward the paralyzed side and away from the side of the cerebral lesion. It may show marked tremor when protruded, as in alcoholism.

The Teeth.—Note carefully the presence or absence of teeth, and the condition of the teeth which are present, as this has an important bear-

ing upon digestion. The notched-peg teeth of inherited syphilis aid us in diagnosis when observed.

The gums are pale in anæmia. The blue line of chronic plumbism (seen, on close scrutiny, to be a series of fine gray-black dots 1 mm. from free margin of gum) should be excluded or noted in every complete examination. The *tonsils* and *pharynx* should also be examined, as it is not uncommon to find here visible and obvious signs of local or general disease, which will explain or help materially in the correct understanding of the condition we have in hand. The isolated white spots of follicular tonsilitis, so easily recognized when we inspect the tonsils, have not infrequently explained a very elaborate group of symptoms.

The Nose.—Inspection of the nose often gives valuable information in acute and chronic diseases; for instance, there may be herpes about the nasal meatus, like that seen on the lips in some acute fevers; and the saddle-back nose of syphilis, though it must be remembered that a similar depression of the nasal bridge occasionally occurs as a result of traumatism.

By the blood vessels, such as abnormal prominence of the superficial temporal or facial arteries, we suspect arteriosclerosis. Ectasia of capillaries of nose and cheeks is a frequent accompaniment of prolonged and liberal indulgence in alcoholic beverages. Dilatation of these capillaries is occasionally due to prolonged exposure to severe weather. Local or general dilatation of the sur-

face capillaries may be caused by local or general interference with the circulation. The pink or red nevus ("strawberry mark") is usually a congenital angioma of the skin and has no general significance.

(7) **The Neck.**—Upper half, front and back (contour, muscles, blood vessels, and larynx).

Inspection of the neck may reveal enlarged lymph glands (so often observed in tubercular subjects) or scars resulting from past suppuration of the glands (also a common result of tuberculous infection); the thyroid enlargement of Graves' disease; the quick, thumping pulsation of the carotid arteries of aortic regurgitation; venous pulsation in the external jugular veins, of tricuspid regurgitation; prominent and rigid sterno-cleido-mastoid muscles of asthma or other obstruction to respiration, and many other valuable signs to help and guide the remainder of our examination.

8. **Hands and Arms.**—*Contour of Fingers.*—Observe distal ends of fingers; note whether normally tapering or clubbed and cyanosed (see Fig. 1).

If the fingers are clubbed and cyanosed, note whether all the fingers on both hands are equally involved, as occurs in some chronic pulmonary diseases and in some cases of malformation of the heart. If only one or two fingers are involved, the cause is local.

Skin and Nails.—Color and condition. Where all the fingers are clubbed at their extremities, the *skin* along the margin and base of the nail

is thin and glistening and the nail is prominently arched from above downward and cyanosed.

Transverse ridges on all *nails* of both hands, at an equal distance from the base of the nail in all, suggest some recent severe illness. This condition, which is due to the death of the old

a b

Fig. 1.—*a*, Clubbed finger; *b*, normal finger.

and growth of new nails, follows some cases of scarlet fever, and the ridge reaches the end of the nail and disappears, in about six months after its appearance at the base of the nail. Such a ridge on only one or two nails is due to local injury or disease.

Compare the size and muscle tonicity of the two arms. Asymmetry may be met with here as a result of accidental injury or nervous disease.

The blood vessels of the hands and arms often yield valuable indications of disease just as those of the face and neck.

The joints may show the visible signs of rheumatism or gout.

The characteristic enlargement of the finger-joints with outward displacement of the phalanges and limited motion render it possible to diagnose rheumatoid arthritis by inspection alone.

NOTE.—Only a few of the many important signs of disease to be gained by inspection of the above structures have been mentioned. The normal contour of the above structures admits of no word description of practical length: this must be learned by repeated, careful and prolonged inspection of many normal types in comparison with the abnormal.

9. **Chest.**—*Contour.* (Compare the two sides.)

Respiratory and cardiac movements (character, type, location, and frequency). Compare the respiratory movements on the two sides; they should be equal.

Blood vessels: Relative prominence and direction.

10. **Abdomen.**—*Contour.* (Compare the two sides.)

Respiratory movements, character, and amount.

Epigastric pulsation, present or absent? and character.

Blood vessels: Relative prominence and direction.

The Recti Muscles.—Note whether either is unduly rigid and prominent as occurs in localized inflammation of peritoneum, or viscera.

Recount in your mind each and every abdominal organ and muscle as you inspect its region.

Note.—Inspection of the *chest* and *abdomen* will be considered further in the sections on examination of these parts.

(11) **Lower Extremities.**—Same as of the hands and arms.

External genitals and anus.

Note.—When "blood vessels" are mentioned above, both the veins and arteries are referred to.

If any peculiar or offensive odor is detected, its character should be noted and its source determined.

The normal appearance and surface color of the skin and mucous membranes, including the tongue, are variable and no description could suffice. This must be learned by observation.

SECTION II.

GENERAL RULES GOVERNING PALPATION, PERCUSSION AND AUSCULTATION.

GENERAL RULES GOVERNING PALPATION.

Palpation is using the sense of touch in physical examination. This method should follow the systematic completion of inspection.

The Subject's Feelings.—Consider the subject's feelings. Avoid harshness and awkwardness, and be on the constant lookout for any indication of pain or local tenderness on the part of the subject. The examiner's hands should not be cold.

Laying on the Hands.—Lay your hands on gently, and where pressure is necessary, increase it very gradually; never apply more pressure than is required to palpate the structure which is being examined. Remember that light palpation usually yields more information than forcible pressure, because it gives rise to less resistance on the part of the subject and also because the examiner's sense of touch is more acute the less pressure exists upon his fingers. The foregoing applies especially to palpation of the abdomen.

The position and manner of laying on the hands varies according to the structure examined, and again in the same structure according to the information we seek; and the beginner cannot give

too much care and attention at the start, to acquire proper technic in palpation. Always apply this method of investigation in a manner appropriate to the structure and condition examined. For instance:

The pulse rate may be obtained by placing the index finger over the radial artery at the wrist without careful attention to the position of the finger or the degree of pressure exerted; whereas, if we wish to determine the qualities of the pulse, we must apply several fingers over the artery, pressing it against the lower smooth surface of the radius in a special manner, which will be described in a subsequent lesson.

Enlarged lymph nodes beneath the skin may be detected by palpating with one hand, just as one may locate a marble in a pillow; but careful, bimanual palpation is often necessary to determine the absence or presence of fluid in the mass (fluctuation).

The Chest.—The manner of laying on the hands is still different when palpating the chest; and here, when we are estimating the expansion or respiratory movement, the hands are applied in a manner different from that employed to estimate vocal fremitus, as will be later on described. (See palpation with reference to the lungs, Section V.)

Points of Tenderness.—When palpating for points of tenderness one or two fingers or the thumb may be used, and pressure should be increased with due regard for the subject's feelings,

as, for instance, in pressing behind the ear for tenderness due to mastoid disease. Where neuritis or nerve tenderness is suspected, apply the pressure over the nerve trunks or, as is the case with the intercostal nerves, where the cutaneous branches pierce the deep fascia.

Tumors.—When palpating a tumor mass in any locality, learn whether circumscribed or diffuse, freely movable or adherent to the skin, bone, muscle or other fixed structure, and the nature of the structures adjacent to it. Also determine the palpable character of the mass itself (*i.e.*, size, form, consistency, and automobility).*

Order of Palpation.—Palpation should be applied in the same anatomical order that is given for inspection. (See General Rules Governing Inspection—Order of Inspection.) In the head, neck, and extremities the two methods may proceed together.

NOTE.—Just as the student must first familiarize himself with the appearance, landmarks, contour, and movements of the *normal* body by inspection, so must he become familiar with the impressions gained by palpation of the *normal* structures and organs before he will be able to recognize departures from the normal. We apply this as well as the other methods of physical examination to each structure in health, in the manner which is peculiarly adapted to detect and estimate changes in that structure resulting from disease or accident.

* By automobility is meant any movement or pulsation which is not caused from without nor by a change of position (gravity).

PHYSICS OF SOUND

Physics treats of the properties of matter and energy, and in its medical application has to do largely with sound. That branch of physics which deals with sound is known as acoustics. Physical diagnosis, then, is information gained through an appreciation of the laws of acoustics.

Sound.—An examination of a sounding body will show that it is in a state of vibratory motion. When a particle of matter is displaced by the application of a force it quickly returns to its original position when the force is removed. The repetition of this displacement and return constitute the oscillations or vibrations which produce sound. The ability to regain equilibrium is owing to the quality of elasticity. The greater the elasticity of a body, the more quickly will the equilibrium be restored, *i.e.*, the more rapid will be the vibratory rate. (The rate of vibrations varies as the square root of the elasticity.)

Sound is, therefore, the oscillations of elastic bodies (air, metal, etc.).

To be perceived by the human ear these vibrations must have a certain frequency, which has been estimated at about 30 per second for the lower range, and at about 38,000 for the upper limits of audition. It is necessary also

that a certain mass of air be set in motion, the vibrations of very minute masses making insufficient impression on the organ of hearing to register as sound. A practical demonstration of this is seen in the use of sounding boards. The vibrations of a violin string (without the sounding box) give but a feeble sound. When attached to the sounding box, however, the vibrations of the string start vibrations in the sounding box which are in turn communicated to a relatively large mass of air, which greatly amplifies the sound. These devices for augmenting sound are known as resonators.

Characteristics of Sound.—*Pitch.*—It was referred to above that sound was the vibration of elastic bodies, and that the rate of vibration was dependent upon the elasticity of the sounding material. (The rate of transmission, too, varies as the square root of the elasticity of the transmitting medium.) The vibration rate determines one of the fundamental characteristics of sound—viz., pitch. The pitch is dependent upon and varies directly with the vibration rate.

In percussion, it is through variations of pitch that many of our deductions are made.

Loudness or Intensity.—Sounds may differ in loudness without alteration of other characteristics. In medical acoustics (in auscultaton) a raising of the pitch is frequently associated with an intensification of the sound, and students

sometimes conclude that this relationship is causal. It is not. The intensity depends on the *amount* of displacement of the elastic masses, which geometrically expressed is the amplitude of the wave. The vibratory *rate* determines the pitch.

NOTE.—In air there is actually no wave motion. Air has only elasticity of volume—not of form. So that what really occurs in air is the production of areas of condensation and rarefaction. This, however, may be expressed in the form of a wave.

Quality.—It is difficult to describe the quality of sound, but it is that characteristic by which the tinkling of a bell may be distinguished from the beating of a drum, or the notes of a canary from those of a robin.

The quality may be graphically represented by the form which the wave assumes, a simple tone giving a simple wave form; a complex sound, a complex wave form. Any form of wave whatever can be compounded of a number of simple waves of different lengths (Fourier's theorem), and when once compounded remains so. (The rate of transmission is the same for long and short waves.) It follows, therefore, that the quality of a sound, once produced, will be difficult to change.

NOTE.—Efforts to change the quality of a sound have been made by the use of mechanical filters, but with rather limited success.

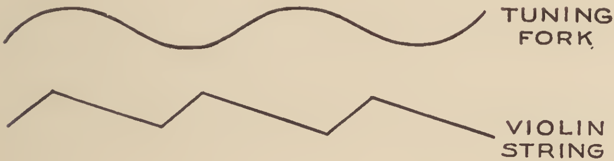
When a string vibrates as a whole (being fixed at either end, these points being called nodes) the sound produced is called its fundamental note. If now a node be placed midway it will vibrate in its halves, and the vibrations will be twice as rapid. In musical instruments there are obtained the fundamental note and the notes from the vibrations of the alequot parts, whose vibration rates bear to the fundamental vibration rate the simple relationship of 2: 3: 4: 5, etc. These are called the overtones or upper partials—and when these overtones are regular and rhythmic, and with the above simple relationship, the effect on the ear is pleasant and the sound is said to be musical. When the overtones are irregular and not rhythmic, the effect is unpleasant, and in this way metallic sounds are produced. A noise is distinguished from a musical note, physically, in that it consists of a number of tones whose vibration frequencies are too near together to be separated by the human car.

As the sound becomes more complex the wave form changes and the quality with it.

In a few instances the wave forms for a few sounds have been plotted, and it has been found that a mellow soft sound (tuning-fork) has a wave form that is gently undulating.

Harsh metallic sounds are associated with abrupt wave forms.

The qualities of the sounds met with in physical diagnosis can only be learned by experience, just as one gets to know the voice of a friend. When the quality for any particular region is altered we know that a physical change has occurred. By attention to these alterations we can very



frequently deduce the nature of the physical change.

Sound is thus seen to have three fundamental characteristics — Pitch, Loudness, and Quality.

Production of Sounds.—The sounds utilized in physical diagnosis are produced as follows:

1. *Percussion.*—Percussion of a region under investigation sets up vibrations in that region with the creation of sound. If the region being investigated be situated close to a body of matter of different structure, a heavy percussion stroke may cause vibrations of the adjacent body, and the sound produced will be a composite one, the resultant of the vibrations of the two structures. Where knowledge is sought of an organ situated close to another, or where the investigation is

concerned with small areas, the percussion stroke, therefore, should be light.

2. The respiratory act sets in motion air currents, which in turn cause various tissues, particularly the air vesicles, to vibrate, Sound-producing motion, as a result of the respiratory act, is excited then in the columns of air and in the vesicular tissues.

3. Use is made of the voice (whispering and articulate) and of cough, the vibratory motion thus produced arising in the larynx.

Modifications of Sound.—1. *Radiation or Diffusion.*—The intensity of sound is lessened by radiation. The greater the distance from a sounding body, since sound spreads radially in all directions, the more diffuse will it be.

The intensity varies inversely as the square root of the distance.

2. *Reflection.*—Sound waves may be turned back upon themselves, as seen in the production of echoes.

3. *Refraction and Absorption.*—In passing from one medium to another of different density, energy is lost both by refraction and absorption. Sound waves in traversing the vesicular structure of the lung pass through vesicular wall, then to the air contained in the vesicle, and then through vesicular wall again, with many repetitions of this process. In consequence, much of the intensity may thus be lost. The behavior of a

feather pillow in lessening sound is well known. The feathers represent the myriads of vesicular walls (there are estimated to be about 400,000,000 vesicles in a human lung) and the air between the feathers, the air contained in the vesicles.

The pleura (normal or thickened) and the chest wall also cause refraction.

4. *Resonance.* — The term resonance or resounding refers to the production of a second sound by the stimulus of a first, and reference was made to the use of resonators in amplifying sound. In the violin the resonator is so made that its wave lengths are in harmony with the note of the string and so amplify the sound. In the human body, however, the resonators (lung cavity, pneumothorax, etc.) are not so constructed, and frequently very unrhythmic overtones are produced, causing metallic sounds. In pneumothorax and pulmonary cavities metallic sounds are thus produced.

Percussion.—It has been referred to above that an important characteristic of sound, valuable in percussion, is that of pitch. It was also pointed out that pitch was dependent upon the rate of vibrations and that the rate, in turn, varied with the square root of elasticity. The quality of elasticity may be regarded as fundamental and no effort to resolve it will be made. Two kinds of elasticity may be spoken of: that of form and

that of volume. When a force is applied to a rigid body, and its form altered, it quickly becomes restored when the force is removed. This restoration is proportional to and in consequence of its elasticity. This quality is marked in steel. The sounds of a tuning-fork are due to its elasticity of form. Air has no elasticity of form, only elasticity of volume, so that the vibrations of air which produce sound are really volume changes, *i.e.*, rapid condensations and rarefactions. The sounds of a pipe organ are due to the volume-elasticity of air. Liquids, as water, have a very high degree of volume elasticity, any condensation being immediately and completely restored. The (volume) elasticity of water is considerably higher than that of air, and in consequence the pitch yielded by fluid on percussion will be higher than that of air. The elasticity of lung tissue while less than that of fluid, is greater than that of air, so that the pitch over lung tissue without air is higher than that of lung containing air and lower than that over fluid. We thus see that the percussion note over fluid is very high pitched—spoken of as flat; that over solidified lung, containing very little air, the note is relatively high pitched—spoken of as dull; that over small areas of consolidation, with more air, the note will be lower pitched—relatively dull or impaired resonance; and that over well aërated lung the pitch is low, spoken of as resonance.

When air is under considerable tension, *i.e.*, compressed, its elasticity is increased, and therefore the pitch raised. In some cases of asthma, where there is great distention of the air vesicles, the percussion pitch is elevated.

Auscultation.—The air as it enters the glottis is put in vibration, and on listening over the trachea, a sound, the result of this vibration, is heard. This sound is transmitted along the air column down to the smaller bronchial tubes. Some of this sound is lost by radiation. It is here that the vesicular structure of the lung is met, and through the process of absorption and refraction (see above) the sound originating at the glottis is largely dissipated. The sounds heard over the chest—*i.e.*, over vesicular lung—differ from those heard over the trachea and are produced (probably) by the vibrations of the air vesicles.

If any of the tracheal sound is transmitted to the ear, it is obscured by the vesicular sound just referred to.

When consolidation of the lung occurs, the air vesicles as air vesicles are done away with, and replaced by a homogeneous transmitting medium, viz., solidified lung. Little sound is lost by refraction or absorption, nor is there (over this area) the obscuring vesicular sound. There is thus transmission (with very slight loss) of the tracheal sound.

What has been said above of the respiratory sound applies equally to the voice sounds.

An accumulation of a considerable quantity of fluid in the chest offers a reflecting surface, and the sound is reflected back into the lung (as in the familiar phenomenon of echo production). At the level of the fluid there may be a condensation of vibrations, with an increase of sound. Below the fluid, little or no sound.

NOTE.—The physical explanations of some of the commonest sound phenomena have been given. A more complete consideration of the acoustics of physical diagnosis is beyond the scope of this book. The student is advised that in his interpretation of the various sound phenomena met with the physical explanations should be kept constantly in view.

GENERAL RULES GOVERNING PERCUSSION.

Percussion, in physical examination, is striking the surface of any part to determine the *quality*, intensity, pitch, and duration of *sound* produced thereby.

Resistance.—The sense of resistance appreciated by the percussing fingers, during the act of percussion, often aids us materially in determining the consistency of underlying structures.

Percussion may be *immediate* or *mediate*.

Immediate percussion is striking the surface directly with the percussing fingers or hammer (plessor), and is, at the present day, confined to the percussion of superficial osseous structures and the detection of fluid waves (fluctuation), as an adjunct to palpation.

Mediate percussion, the method commonly employed, is striking an object (pleximeter), which is applied directly to the surface.

Plessor (Hammer).—It is claimed here that the fingers or finger (index, middle, and ring, or either one or two of these) should be employed as plessor in preference to any artificial instruments. The reasons being that one often obtains valuable impressions from the sense of resistance felt by the percussing fingers which are lost when an artificial hammer is used. It also obviates the necessity of having a special instrument at hand to employ this method of physical exploration.

Pleximeter (the Mediate Substance, or Medium).—The pleximeter is the object which is

applied directly against the surface and receives the blow of the plessor in *mediate* percussion. Here also the finger is preferable to artificial materials, for the same reasons given in the case of the plessor; though the finger possesses additional advantages here, namely, it adds no foreign quality to the percussion note elicited, —and it is capable of being more accurately adjusted to the surface percussed than is possible with any artificial instrument.

General Technic of Percussion.—The finger employed as a pleximeter must be applied evenly to the surface with slight pressure, which must be equal throughout. Be especially careful that no air space remains between the finger and the surface percussed at any point.

In applying the blow, the forearm of the percussing hand must be held fixed and motionless. The hand must move antero-posteriorly at the wrist—motion taking place at the wrist-joint only. The fingers used must be adjusted firmly and rigidly against one another, so that their ends are on the same plane and come in contact with the pleximeter simultaneously and with equal force. You must practice the above motion until you can accomplish it without having your mind centred upon your own hand and arm.

The plessor must recede from the pleximeter the instant after the blow is struck, for if they remain in contact after the blow the vibrations elicited will be interfered with, the resulting sound is muffled.

The Percussion Blow.—When tissues at the same depth from the surface, or corresponding regions on the two sides, are compared, the percussion blow should be of uniform force.

The more forcible the blow, the deeper and more diffuse will be the area of tissues set in vibration, and *vice versa*.

To obtain the percussion note of a superficial organ, or a restricted area, employ light percussion—a light blow—and *vice versa*.

The blows must follow each other not too rapidly, else the duration of the sounds elicited cannot be appreciated.

Fundamental Elements of Sound.—Percussion sounds, in common with all other sounds, are made up of four fundamental elements: *quality*, *pitch*, *duration*, and *intensity*.

Quality.—In physical examination, quality is by far the most important element of sound. It is the quality which enables us to know any given sound from every other sound. Quality suggests the source of a sound in general life, and enables us to tell the sound produced by one musical instrument from that produced by another instrument, regardless of pitch, intensity, and duration, (*e.g.*, a violin from a horn). Furthermore, everyone has the power to distinguish the differences in quality, but few have an ear which enables them to determine with certainty the finer differences of pitch, duration or intensity in sounds of the same quality. So we estimate

the physical condition and relations of internal structures and organs of the human body, more by the *quality* of percussion sounds than by any other elements of these sounds.

Terms of Quality.—Terms used to signify the quality of sounds may be general, restricted, or specific in meaning and application.

General.—Some general terms of quality are: FLAT, DULL RESONANT, and TYMPANITIC.

Restricted.—Such terms as DULL TYMPANITIC, VESICULAR, AMPHORIC, CRACKED-POT, and the like have a more restricted application.

Specific.—OSSEOUS, NORMAL PULMONARY RESONANCE, EMPHYSEMATOUS, and others are specific in their application.

Most of the terms given above are self-explanatory. The three terms "flat," "dull," and "resonant" apply to three arbitrary divisions of sound quality, there being no sharp line of demarcation between them. In actual fact, all sound is resonant to some degree. In practice we apply the term flat to those sounds which have so little resonance that it can hardly be appreciated.

The student must understand that flatness and resonance are the two extremes in body percussion sounds, that flatness suggests solidity (by solid or fluid), and resonance space or spaces containing air or gas; and that dullness is the common ground between, where the qualities of flatness and resonance are blended in varying degrees.

We elicit flatness over a solid mass or accumulation of fluid of considerable size where they are in contact with the chest or abdominal wall. If the mass or accumulation of fluid is small and in

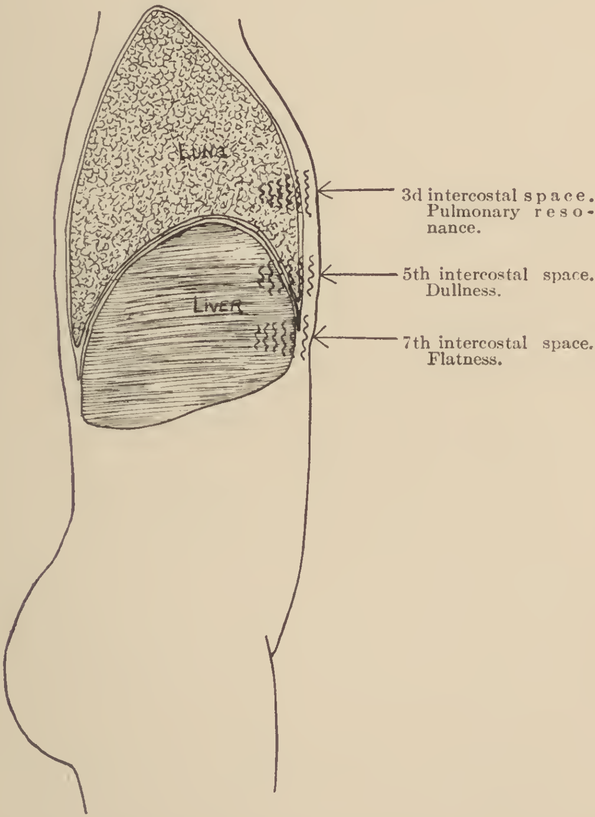


Fig. 2.—Diagram showing how pulmonary resonance, dullness, and flatness is produced on light percussion along the right mammillary line in the normal subject.

direct contact with hollow viscera or lung tissue, as in the case of the heart, even a light percussion stroke will elicit a dull (not flat) sound, because the neighboring structure is set in vibration to a slight degree, adding an appreciable resonant quality to the sound.

In some subjects, percussion over the liver in the seventh intercostal space, right nipple line, if the stroke is light, does not add either tympanitic resonance from the abdomen nor pulmonary resonance from the lung to any considerable extent. Therefore, the percussion sound elicited at this point is practically flat, though not absolutely flat, as is elicited over a large amount of fluid in the pleural or peritoneal cavity. In view of the fact that in many cases it is quite impossible to elicit an absolutely flat note over the normal liver with even the lightest stroke, it is advisable to use the term "absolute liver dullness" (not "liver flatness") in this connection.

The best available illustration of flatness in the normal is obtained by percussion over the fleshy part of the thigh.

Pitch.—The percussion note elicited over a given region may be normal, elevated, or lowered in pitch. The greater the tension of the underlying tissues, the higher will be the pitch of the percussion sound, and the lower the tension the lower the pitch.

All else being equal, the greater the amount of solid or fluid in proportion to air or gas in a

given region or part, the higher will be the pitch of the percussion sound elicited over that region, because the tension of the tissue set in vibration is proportionately greater.

A "FLAT" sound is HIGH in PITCH.

A "DULL" sound, though high, *is not so high in pitch* as a "FLAT" sound.

A "RESONANT" sound is LOW in PITCH.

Duration.—The *duration* of a sound (from a single blow) corresponds to its pitch. The higher the pitch, the shorter the duration, and *vice versa*.

Intensity.—The stronger the blow over a given region in a given subject the greater will be the *intensity* (volume) of sound produced, if the deep relations remain the same.

All else being equal, the greater the degree of elasticity of the tissues percussed, the greater the intensity of the percussion sound, and *vice versa*.

Intensity is also increased by an increase in the relative amount of air or gas, and decreased by the relative amount of solid or fluid under the region percussed. In most instances, the higher the pitch the less the intensity of a percussion sound, and *vice versa*.

So that, all else being equal, a flat sound has the least intensity, a dull sound more than the flat, and a resonant sound still more. Intensity increases with increase of resonance.

Order of Percussion.—CHEST.—Consider *lungs*

and *pleura*, *heart*, *pericardium* and *great vessels*, *glands* and *parietes*, including surface blood vessels.

ABDOMEN.—Consider all abdominal contents and structures and each organ separately from above downward, parietes and surface blood vessels.

NOTE.—Percussion of the nervous and osseous systems will not be considered in this work.

GENERAL RULES GOVERNING AUSCULTATION.

Auscultation, in physical examination, is listening to the various sounds produced within the body to ascertain their significance.

Immediate and Mediate.—As in percussion, auscultation may be *immediate*, with the ear applied directly to the surface of the body with or without a thin layer of cloth between; or *mediate*, by the use of a stethoscope, which should always be applied directly to the skin, to avoid extraneous friction sounds.

There are undoubtedly some sounds the character and significance of which can best be determined through the stethoscope (especially in the heart and blood vessels), yet there will be occasions when it is necessary to auscultate and a stethoscope may not be at hand. Therefore, you should, by practice, make yourself familiar with both immediate and mediate auscultation. The condition of the subject in some cases and in others the dictates of modesty will demand the use of the stethoscope through all of auscultation.

Many writers claim that immediate auscultation is best for examination of the lung, and mediate auscultation best for examination of the heart.

FIG. 3.—A stethoscope.

Choice of a Stethoscope.—When choosing a stethoscope, select one which has the broadest possible range of usefulness. This, I believe, is

accomplished by the simplest form of binaural instrument (see Fig. 3). (The monaural stethoscope is used almost exclusively in Europe, but I believe it to be of less practical value than the binaural instrument).

The ear-pieces of your stethoscope should fit the ears comfortably, and the spring be only strong enough to hold the instrument in position; if it should be too strong, the pressure in the external auditory canal soon becomes very uncomfortable and interferes with hearing.

A flexible stethoscope (with rubber tubes) has the advantage that it can be easily folded and carried in the pocket, but the tubing should not be too small nor too flimsy.

The flat chest-piece of the Bowles' stethoscope is convenient for examining parts of the chest which, for any reason, cannot be freely exposed.

Phonendoscopes (instruments with a drum to magnify sound) should not be used in the early years of your study and practice of physical examination, because they would establish a false idea of the relative character and volume of the various sounds.

When applying either the stethoscope or the ear in auscultation, you should take care that it fits evenly to the surface, touching in all its circumference, so as to shut out all extraneous sounds. Never press the chest-piece of the stethoscope against the surface with sufficient force to cause discomfort to the subject.

Order of Auscultation.—Here you should follow the anatomical order observed in percussion. Auscultation should be applied to the vessels of the neck, in connection with auscultation of the heart.

NOTE.—In physical examination of the abdomen, auscultation is of very limited use, as will be hereafter explained.

Auscultatory percussion is, as the term implies, the simultaneous employment of auscultation and percussion combined. The stethoscope is applied over the organ to be outlined and percussion applied about it. The instrument may or may not be moved from point to point, but the pleximeter must be moved about. The character of sound elicited changes as the percussion blow is struck beyond the margin of the organ under examination. Auscultatory percussion is often serviceable in marking out the limitations of hollow abdominal viscera. The transmission of metallic sounds through the chest in pneumothorax (coin test) is a modification of auscultatory percussion.

SECTION III.

SURFACE MARKINGS.
TOPOGRAPHY OF THE HEAD, NECK, UPPER EXTREMITIES, AND CHEST.

Definition.—By surface markings, or topography, is meant the prominences, depressions, and imaginary lines and points upon the surface of the body, by which we may locate the position and limitations of underlying structures.

No reference will be made herein to surgical or neurological topography.

HEAD AND NECK.

The superficial temporal artery lies just beneath the skin, in the temporal fossa ("temple"), following a generally vertical course, where it is available for palpation and often for inspection, as in marked arteriosclerosis when it is seen as a tortuous, throbbing cord; and aortic insufficiency when its pulsations are often distinctly visible.

The facial artery lies just beneath the skin, crossing the lower border of the inferior maxilla at the anterior border of the masseter muscle, where it is available for palpation; and occasionally for inspection, as in arteriosclerosis and aortic regurgitation.

The carotid artery ascends along the outer side of the trachea. The sterno-cleido-mastoid muscle lies over it in the lower part of the neck. This artery is available for palpation and frequently for inspection (and auscultation in some conditions).

The external jugular vein descends vertically from the angle of the jaw nearly to the upper border of the clavicle, in the supraclavicular fossa. It is superficial to all muscular tissue and is available for inspection, palpation, and auscultation in some conditions.

It is in this vessel that the venous hum of anæmia is heard and venous pulsation observed, when they exist.

The subclavian artery and vein lie deep in the lower part of the supraclavicular fossa.

The parotid gland, covered partially by the lobe of the ear, extends over the posterior portion of the masseter muscle and back behind the posterior border of the ramus of the inferior maxilla.

Swelling of this gland tilts the lobe of the ear outward (as in mumps).

The submaxillary gland lies deep in the submaxillary triangle, close to the inner surface of the inferior maxilla. It is distinctly palpable when enlarged.

The Lymphatic Nodes.—Generally speaking, the superficial nodes of the head and neck lie posterior to a vertical line dropped through the external auditory meatus, and the deep nodes lie

anterior to this line: the superficial auricular, being an exception, lies just in front of the lobe of the ear. A small node lies over the mastoid process just behind the ear and is usually palpable early in mastoid suppuration.

The Thyroid Body.—The isthmus of the thyroid crosses over in front of the trachea just below the larynx, the two lateral lobes lying close to the upper part of the trachea on either side.

The thyroid, lymph, and salivary glands are not palpable when normal.

The larynx and trachea are in the median line, with the œsophagus descending between them and the cervical vertebræ.

NOTE.—The internal jugular vein, which runs down just to the outer side of the carotid artery, is very rarely of importance in the usual physical examination.

UPPER EXTREMITIES.

The radial and brachial arteries, median basilic vein, ends of fingers, and lymph nodes are of special importance in general physical examination.

The radial artery, as it lies upon the smooth anterior surface of the lower end of the radius, is easily palpable. In some cases, such as extreme emaciation, arteriosclerosis or aortic regurgitation, its outline and pulsations are visible.

One or both radial arteries may take an anomalous course, the commonest being that the artery turns outward at a point one to two inches above the lower end of the radius, passing to the dorsal

surface; this must be remembered when palpating for the pulse.

The pulsations of the radial artery cannot usually be seen in health.

The brachial artery, descending along the inner side of the arm, is not usually available for inspection,* though it may be palpated by pressing it outward against the humerus above, and backward in the lower part of the arm.

The median basilic vein, quite superficial and easily seen, except when imbedded in a great amount of adipose tissue or œdema, runs obliquely upward and inward in front of the elbow-joint; it is distended and made to become prominent by digital pressure just above and anterior to the internal epicondyle of the humerus. This is the most convenient vessel from which to draw blood (for diagnostic or therapeutic purposes) as well as for intravenous injections.

You should familiarize yourself with the range of normal shape and color of the ends of the fingers (including the finger nails). Note also the degrees of prominence of the superficial veins in the upper extremity, as well as in other parts of the body, compatible with health.

Lymph Nodes.—The most frequently enlarged and palpable group in the arm is the *supratrochlea* (epitrochlea), which lies rather superficially just above the internal epicondyle of the humerus.

*Except where there is arteriosclerosis or aortic regurgitation.

The *anti-cubital* group is in front of the elbow-joint.

The AXILLA contains lymph nodes, but none of the lymph nodes are palpable when normal

THE CHEST.

Contour.—The general shape and contour of the chest varies so widely within the normal that any word description of practical length is

FIG. 4.—Thin normal subject; clavicles prominent.

inadequate. Even in health the prominence of bony landmarks and the presence of surface depressions depend upon peculiarities of build in different individuals, as well as the amount of adi-

pose tissue and the various attitudes habitual to different people, due to occupation or habit.

To illustrate the range of normal contour, examine a thin man who is in perfect health. His clavicles will be moderately prominent. Another man who is stout, but in no better health, will present depressions or grooves over the course

FIG. 5.—Fat normal subject; clavicles not prominent.

of the clavicles (see Figs. 4 and 5). Furthermore, the thin man may gain forty pounds in weight, when his clavicles, instead of forming a ridge, will be marked by a depression along their course.

Another equally healthy subject of average build may relax his muscles, allowing his shoulders to slouch forward, and his clavicles will form prominent ridges with marked depressions above and below them. But when he throws his

FIG. 6.—Normal subject; shoulders erect, clavicles not prominent.

shoulders back, allowing his chest to expand, the clavicles relatively recede, leaving depressions along their course (see Figs. 6 and 7).

Besides the conditions mentioned above, the contour of the chest is influenced in health by

sex, age, muscular development, and occupation or habit.

Only careful and repeated observation can teach one the variations in normal contour of any compound part of the body.

Fig. 7.—Same normal subject; shoulders slouched forward, clavicles prominent.

There are numerous set types of chest deformities to which special names have been applied (*e.g.*, rachitic, pterygoid, phthisical, barrel, pigeon-breast, and others) which you will learn in the course of your medical study.

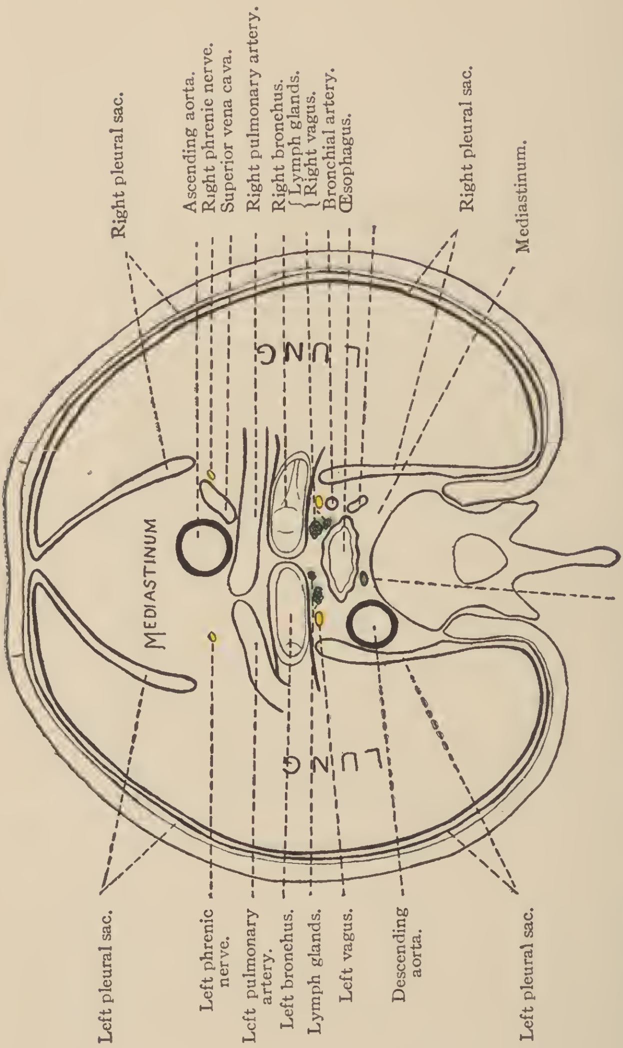


FIG. 8.—Diagram showing antero-posterior relations of the important structures in the thorax on a level with the lung roots, the heart is placed below and anterior to this region (after Le Fevre).

Surface Veins.—The veins of the upper anterior surface of the chest are tributaries of the internal mammary veins, which are in close relation to the pleura near the apices of the lungs, just before they join the innominate veins. Therefore if the lumen of the internal mammary vein is compromised by inflammatory processes centred in the adjacent pleura (as is seen in some cases of pulmonary tuberculosis), or by pressure from enlarged lymph nodes or neighboring viscera, distention of the anterior superficial veins on the corresponding side of the chest will be observed. If the innominate vein is involved in a similar way, the veins of the arm and neck on the same side take part in the distention and prominence.

Many of the superficial veins of the lower part of the anterior and antero-lateral walls of the chest descend to join the abdominal veins.

NOTE.—The superficial capillaries of the chest wall, so ably discussed by Sahli, will not be considered in this work.

SURFACES OF THE CHEST.

The surfaces of the chest are ANTERIOR, POSTERIOR, and TWO LATERAL.

Anterior surface is bounded above by a line curved upward, connecting the outer ends of the middle thirds of the clavicles; laterally by vertical lines dropped through the ends of the curved line mentioned; and below by the inferior costal margin.

Regions of the Anterior Surface.—Centrally lies the *sternal* region, limited by the borders of the sternum and subdivided into upper sternal and lower sternal by the angulus sterni (junction of manubrium and gladiolus, an easily palpable transverse ridge), where the second costal cartilage articulates with the sternum. The *suprasternal* region is that area lying immediately above the sternum.

Laterally the *supraclavicular* region (right and left) is that part of the anterior surface above the clavicle. The *clavicular* region is that limited by the inner two-thirds of the clavicle. The *infraclavicular* region extends from the clavicle to the upper border of the third rib, and from this to the sixth rib is the *mammary* region; below which lies the *inframammary* region extending to the inferior costal margin.

Posterior surface, bounded above by a horizontal line through the spine of the seventh cervical vertebra (vertebra prominens); laterally by a vertical line through the upper end of the posterior axillary fold; and below by the twelfth rib.

Regions of the Posterior Surface.—The *interscapular* region is that portion between the scapulæ. The *scapular* regions, right and left, over each scapula. The *infrascapular* region is all that portion of the posterior surface of the chest lying below the inferior angles of the scapulæ.

Lateral Surfaces.—The areas lying between the anterior and posterior surfaces on either side.

They are subdivided into *axillary* and *infra-axillary* regions by a horizontal line through upper border of the sixth rib in the nipple, or mammary line.

TABLE OF UNDERLYING CONTENTS IN THE REGIONS OF THE CHEST.

ANTERIOR SURFACE. (See Fig. 9.)

Right Supraclavicular	*Suprasternal*	*Left Supraclavicular*
The apex of the right lung. The subclavian vessels. The termination of the external jugular vein. The pleura. Lymph nodes.	The trachea. The œsophagus (very deep). (The aortic arch may be displaced up into this region by pathological changes. The common carotid artery and internal jugular vein lie on the boundary between this and the supraclavicular region.) The thyroid.	The apex of the left lung. The subclavian vessels. The termination of the external jugular vein. The pleura. Lymph nodes.

Right Clavicular	*Upper Sternal*	*Left Clavicular*
The lung. The innominate vein. The pleura. Lymph nodes. *Right Infraclavicular* The lung. The right primary bronchus. The superior vena cava. The arch of the aorta. The pleura.	The trachea and primary bronchi. The ascending and transverse arch of the aorta. The innominate artery. The superior vena cava. The left innominate vein. Both lungs. The pulmonary artery. The pulmonary valve, (at the extreme left border). The pleura. The appendix of the right auricle. The apex of the pericardium. (The right innominate vein is on the boundary between this and the right infraclavicular region.) The thymus. Lymph nodes.	The lung. The innominate vein. The common carotid. The subclavian artery. The pleura. Lymph nodes. *Left Infraclavicular* The lung. The primary bronchus. The left auricle. The pleura.

Right Mammillary

The lung.
The right auricle.
The diaphragm.
The right bronchus and its branches.
The liver.
The pleura.

Lower Sternal

Both lungs.
The pericardium.
The base of the right ventricle.
The base of the left ventricle.
The left auricle (deep).
The right auricle.
The mitral, aortic and tricuspid valves.
The inferior vena cava.
The pleura.

Left Mammillary

The lung.
The right and left ventricle.
The left bronchus and its branches.
The diaphragm.
The stomach.
The pleura.

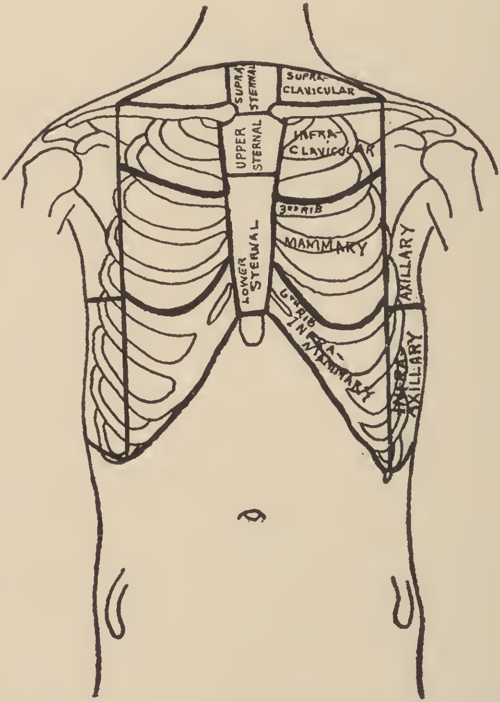


Fig. 9.—Regions of the anterior and lateral surfaces of the chest.

Right Inframammary

The lung.
The diaphragm.
The liver.
The pleura.

Left Inframammary

The lung.
The diaphragm.
The liver.
The stomach.
The pleura.

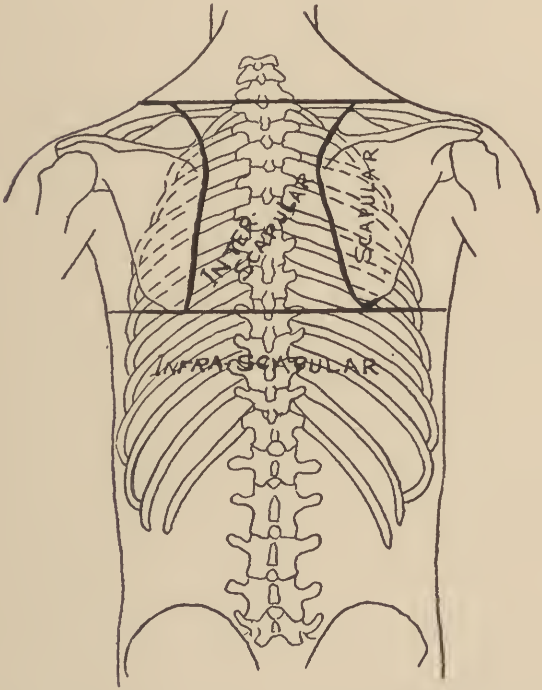


FIG. 10.—Regions of the posterior surface of the chest.

LATERAL SURFACES. (See Fig. 9.)

Right Axillary

The lung.
The pleura.
Lymph nodes.

Left Axillary

The lung.
The pleura.
Lymph nodes.

Right Infraaxillary	*Left Infraaxillary*
The lung. The diaphragm. The liver. The pleura.	The lung. The diaphragm. The spleen. The stomach (this gives a tympanitic quality to the percussion sound in this region, if it contains gas). The pleura.

POSTERIOR SURFACE. (See Fig. 10.)

Right Scapular	*Interscapular*	*Left Scapular*
The lung. The pleura.	The lungs. The trachea and bronchi. The aorta. The œsophagus. The thoracic duct. The venazygous major.	The lung. The pleura.

INFRASCAPULAR.

Right Side	*Median Area*	*Left Side*
The lung. The diaphragm. The liver. The kidney. The pleura.	The aorta. The oesophagus. The thoracic duct. The venazygous major. The diaphragm.	The lung. The diaphragm. The spleen. The kidney. The pleura.

Lines.—When a line is mentioned in citing the location of a structure or phenomenon, a vertical line is meant, unless otherwise stated.

For instance, the median line, mammary or nipple line, midclavicular line, midaxillary line, midscapular line, and the parasternal line which is midway between the outer edge of the sternum and the midclavicular line.

It is obviously necessary to mention the side—right or left—when applying the above terms, except in the case of the median line.

SECTION IV.

SURFACE MARKINGS (CONTINUED), AND INSPECTION OF THE CHEST, WITH REFERENCE TO THE LUNGS.

SURFACE MARKINGS OF THE CHEST.

The sterno-clavicular articulation on the right side marks the termination (bifurcation) of the innominate artery.

The angulus sterni is a palpable, and in many cases visible, transverse ridge on the anterior surface of the sternum at the junction of the manubrium and body. It marks the level of the second costal cartilage and rib, the bifurcation of the trachea and the under surface of the arch of the aorta, with the structures forming the root of each lung just beneath it. The sternal angle, marking the level of the second costal cartilage and being palpable in nearly all subjects, is usually the best starting point from which to count the intercostal spaces or ribs.

The junction of the xiphoid cartilage with the sternum marks the sternal articulation of the seventh rib. It is easily palpated in most subjects and is therefore a good fixed landmark.

The nipple, though a fairly reliable landmark in men of average build, is totally unreliable as a landmark in most women.

The tip of the spinous process of the seventh cervical vertebra (vertebra prominens) is on a level with the apices of the lungs.

The interval between the spinous processes of the second and third dorsal vertebræ is the level at which the main fissure (separating the upper and lower lobes) of the lung reaches the surface posteriorly. This fissure passes outward, forward, and downward on the surface of the lung, to join the inferior border of the lung in the parasternal line. It is therefore seen that the third intercostal space, in the interscapular region, contains the extreme apex of the lower lobe near the vertebral column and a small portion of the upper lobe near the scapula. The area of upper lobe available for accurate physical exploration, on the posterior surface of the chest, is very small, and is confined to the first, second, and outer part of the third intercostal spaces. The remainder of the posterior surface, not covered by the scapulæ, is occupied by the lower lobes, which extend down to the tenth rib on both sides. The pleural reflections extend about an inch and a half further down on both sides; to the twelfth rib posteriorly (see Fig. 11).

When the angle of the scapula (inferior angle) is referred to as a fixed point, it is understood to be in its anatomical position (over the seventh rib).

The Trachea and Bronchi.—The trachea, near its lower extremity, turns slightly to the right of

the median line to give place to the transverse arch of the aorta. On a level with the angulus sterni anteriorly, and the lower part of the 4th dorsal vertebra posteriorly (a little to the right

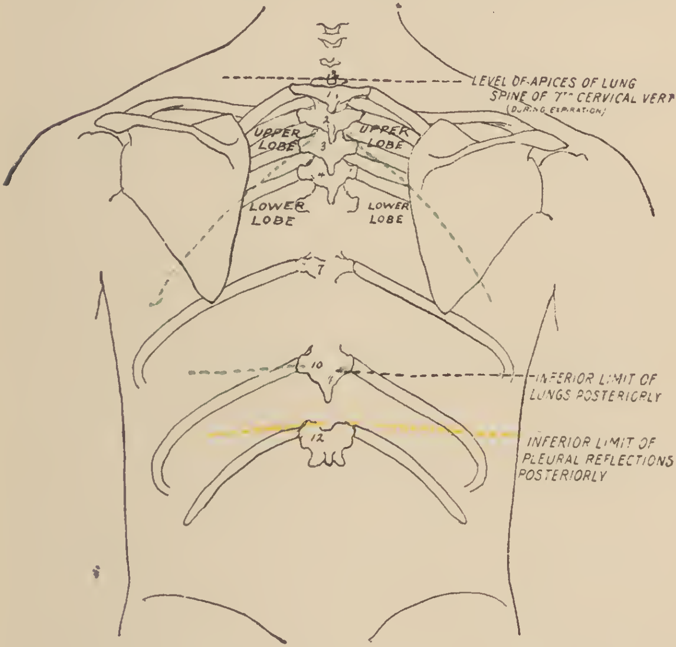


FIG. 11.—Topography of lungs, pleura, and fissures in the posterior surface of the chest.

of the median line) it divides into *right* and *left primary bronchi*. The right primary bronchus, larger and shorter than its fellow, continues downward and to the right in almost the same direction as the final portion of the trachea. The left

primary bronchus, smaller, longer, and nearer horizontal, leaves the trachea with a sharp change of direction. (See Figs. 12 and 13.) The first branch (the eparterial bronchus) from the right primary bronchus, is given off near the tracheal

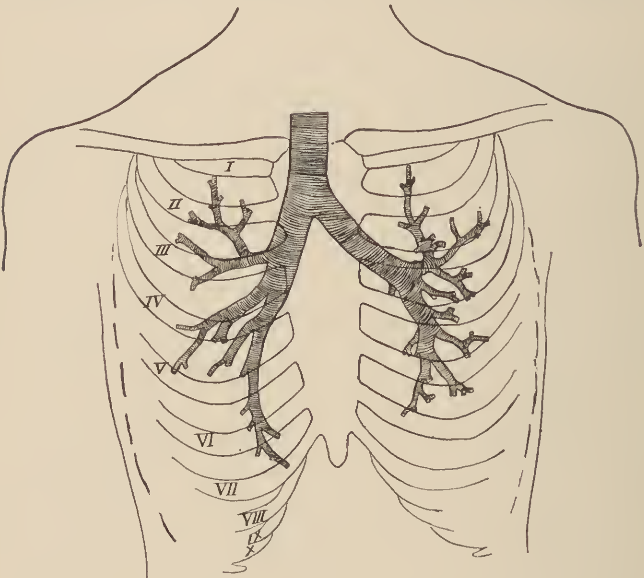


FIG. 12.—Diagram showing relations of trachea and bronchi to anterior chest wall (after Le Fevre).

bifurcation, and before the primary bronchus has entered lung tissue. This branch is rather large, and takes a course directly toward the apex of the right lung.

The left primary bronchus, longer and smaller in calibre than the right, is surrounded and muf-

fled by lung tissue before any branch springs from it. The left bronchus is further muffled by the arch of the aorta, which hugs it above at its very origin.

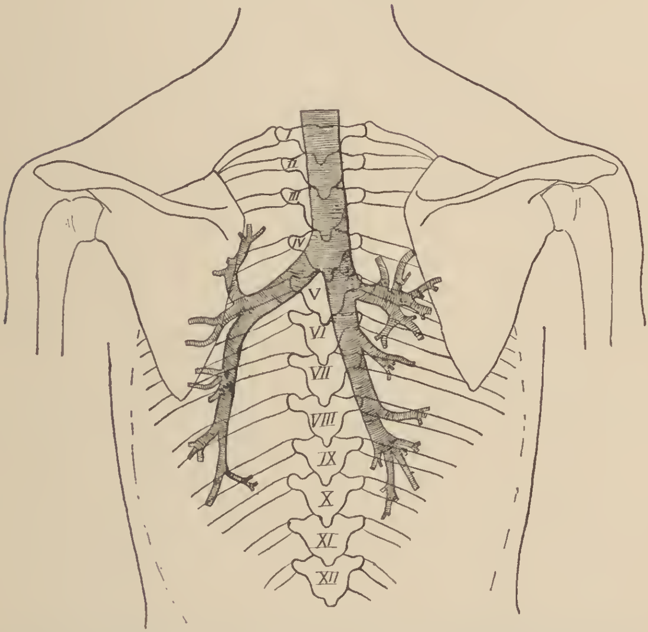


FIG. 13.—Diagram showing relations of trachea and bronchi to posterior chest wall (after Le Fevre).

NOTE.—The primary bronchi (the right more than the left) impart a varying degree of tubular quality to the respiratory sounds heard, anteriorly at the inner portion of the infraclavicular regions and posteriorly in the fourth intercostal spaces (in the interscapular region).

Lungs and Pleura.—The apices of the lungs extend one-half to one and one-half inches above the clavicles, rising with inspiration. The anterior borders of the two lungs are in apposition in the median line from the middle of the manubrium

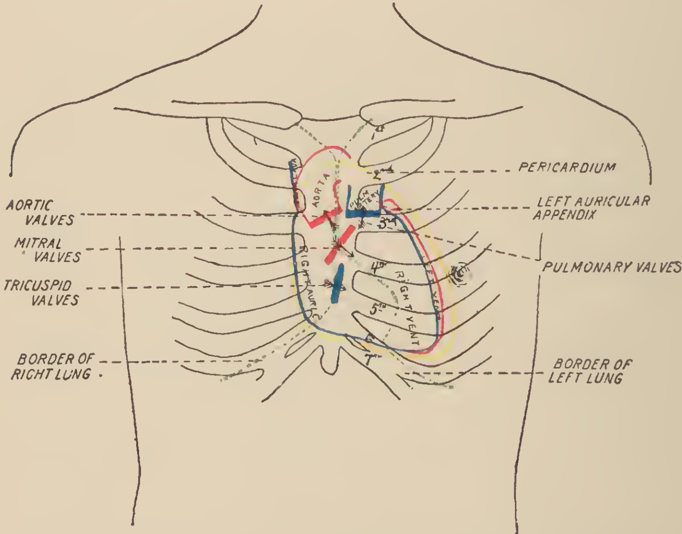


FIG. 14.—Diagram showing the position of the heart, great vessels, and valves. The borders of the lungs are indicated by green dotted lines. Note.—The arrows indicate the direction of normal blood currents at the valves.

to the level of the fourth costal cartilage. At this point the left turns outward and downward nearly to the site of the apex beat (fifth intercostal space, about three inches to left of the median line), then downward and inward to the sixth costal cartilage, exposing part of the heart and pericardium. The

anterior border of the right lung continues down in the median line to the sixth costal cartilage. (see Fig. 14).

The lower borders of both lungs follow the sixth costal cartilage and rib to the mammillary or nipple line and continue backward crossing the eighth rib in the midaxillary line, being on the level of the tenth rib posteriorly (see Fig. 15).

The main fissure, indicating the upper border of the lower lobe on both sides, appears in the lower border of the lung in the parasternal line, and runs obliquely upward and outward on the surface of the lung to its posterior border by the side of the vertebral column, crossing the third intercostal space in the interscapular region (see Fig. 11). *The short fissure* (usually present) on the right side, runs from the fourth costosternal articulation horizontally outward to join the main fissure (see Fig. 16).

The capacity of the right lung is greater than the left, in the ratio of eleven to ten.

The pleura covers most of that part of the pericardium not covered by lung. Both pleural sacs extend below the inferior borders of the lungs, to the tenth rib in the midaxillary line and to the twelfth rib posteriorly near the vertebral column. So that, with the subject erect, the pleural reflections reach their lowest level in the midaxillary line (see Fig. 15). All of the pleural reflections are encroached upon by lung, during inspiration, and permanently so when there is pulmonary

emphysema, in which condition the area of absolute cardiac dullness may be almost completely replaced by pulmonary resonance.

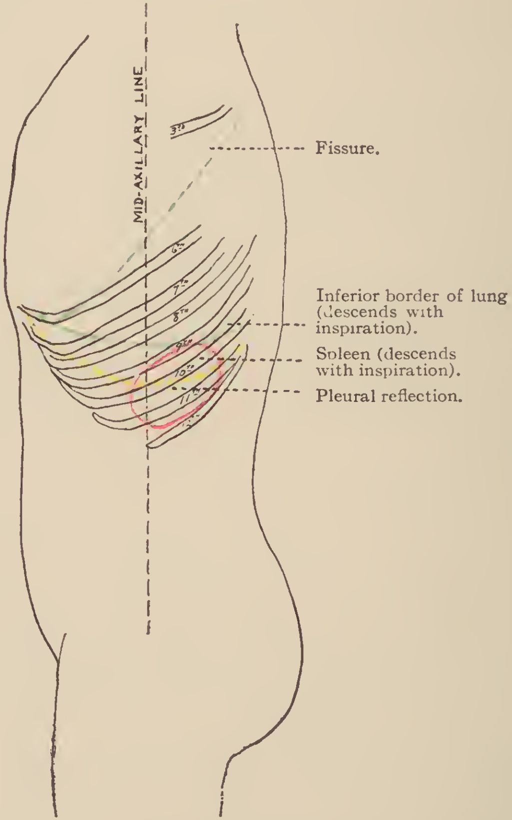


FIG. 15.—Diagram showing the position of the interlobular fissure, the inferior border of the lung, and the pleural reflection, laterally (similar on both sides); and the position of the spleen.

The Apex Beat.—Since the presence or absence, faintness or prominence, and the position of the visible, palpable, and audible apex beat of the heart is of importance in determining the condition of neighboring lung and pleura in many cases, you

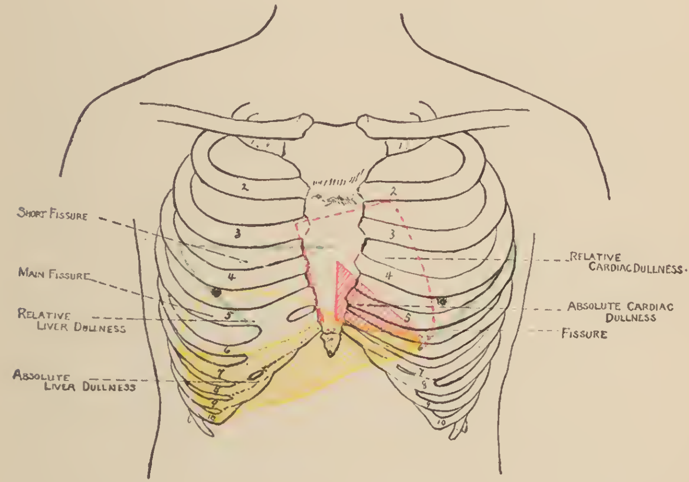


Fig. 16.—Diagram showing absolute dullness and relative dullness of liver and heart; and the approximate position of interlobular fissures of the lungs—anteriorly.

should note these points during physical examination of the lungs and pleura. The normal site of the apex beat is in the fifth intercostal space about three inches to the left of the median line. The area of visible motion is normally confined to a circle about one inch in diameter.

INSPECTION WITH REFERENCE TO THE LUNGS.

The subject should be stripped to the waist. If his condition permits it, he should stand or sit erect facing the greatest source of light, with his arms hanging passively by his sides. The examiner should stand three to six feet in front of the subject.

Attitude and Contour.—Observe first the general attitude and contour of the chest. A perfectly healthy chest may not be exactly symmetrical on the two sides. One shoulder may be higher than its opposite, or one side of the chest may be slightly larger than the other; though such asymmetry should be carefully noted as they are not infrequently the result of past or present disease or accident in lung or pleura. Look carefully for any unilateral or circumscribed deformities, bulging or depression. Besides the set types of chest deformities, we may observe unilateral or circumscribed enlargements or retractions as a result of disease of the lung or pleura. Depression or retraction of the supra- and infraclavicular regions is frequently seen as a result of disease at the apex of the lung, especially in pulmonary tuberculosis.

It must not be forgotten that circumscribed bulging, depressions, or deformities are occasionally seen in this as in other parts of the body, as a result of disease or injury of the bones or soft tissues making up the parietes.

The color and condition of the skin and veins,

especially the degree and extent of any venous distention, should be carefully observed.

Note the cardiac apex beat, whether visible or not; its position (it is displaced to the right when there is considerable fluid in the left pleural sac); whether prominent or only faintly visible or absent (as noted in some cases of pulmonary emphysema); if normally circumscribed and confined to an area one inch in diameter, or diffused over a greater area (as seen in some cases of pulmonary tuberculosis with retraction of the anterior border of the left lung).

Respiratory Movements.—Observe the respiratory movements, first when the subject breathes naturally and again when he is told to breathe deeply.

Anatomically, there are two types of breathing: superior costal, or costal; and diaphragmatic, or abdominal. The former is usually more prominent in women and the latter in men.

Compare the prominence and movement of the ribs on the right with those on the left side. They should be of the same prominence on the two sides, rising and receding equally in corresponding regions, on both sides simultaneously. Special notice should be given to the supra- and infraclavicular regions in this connection.

Expansion with inspiration may be normal, *diminished* or *limited*, *increased* or *exaggerated*, or *absent* on one side. If both sides are either increased above, or diminished below the average

over the entire chest, it does not signify that the subject is diseased; for, so long as the two sides expand equally, variations in the degree of expansion may be due to habit. If, however, the lower part of the chest expands normally and the upper part poorly or not at all, the supra- and infraclavicular regions on one or both sides remaining depressed throughout the respiratory act, we should be suspicious of the existence of disease of the lung in those regions.

There may be retraction of the lower ribs with the inspiratory effort instead of expansion. Retraction of the lower ribs and the episternal notch with the inspiratory effort is due to partial or complete occlusion of the glottis or trachea.

If the respiratory movements are not uniform on the two sides, note which is limited, which exaggerated and whether inspiration is suddenly checked on either side because of pain, as occurs in pleurisy.

You must learn to distinguish between true eccentric expansion of the chest and simple elevation of the sternum and ribs by the extraordinary muscles of respiration with little or no expansion. The latter occurs with each inspiratory effort in those cases of barrel-shaped chest in the asthmatic or aged, where the chest is rounded, the sternum prominent, the antero-posterior diameter increased, and the sterno-cleido-mastoid muscles stand out prominently.

Where the expanding capacity of one lung is

compromised and diminished, there is usually a corresponding exaggeration of the expansion on the opposite side.

Note the frequency of respirations (they should be sixteen to nineteen per minute in a healthy adult); whether shallow or full or jerky, stertorous, labored, and whether or not the extraordinary muscles of respiration stand out prominently (the sterno-cleido-mastoid muscles especially).

After complete inspection of the anterior surface the subject should turn about for equally careful inspection posteriorly, then to either side for inspection of those surfaces.

The diaphragmatic phenomenon (Litten's sign) is the visible depression of the sixth and seventh (and in some cases the eighth) intercostal spaces, placed horizontally, in the infraaxillary regions, during inspiration. This depression is caused by the suction force produced by the descent of the diaphragm, which is, as it were, peeled away from the chest wall at the site of the inferior reflections of the pleural sacs, during inspiration. The same suction force, or negative pressure, causes expansion and descent of the inferior borders of the lungs, thus filling out the depressed intercostal spaces from above downward. The depressions travel downward along the intercostal spaces one to two inches during the inspiratory act, and disappear when inspiration is complete. This phenomenon can be observed in most normal chests (not in all) by the following technic:

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Have the subject lie upon his back on a flat surface, with his arms raised above his head. Have a single source of light entering the room from the direction of the subject's feet. The observer standing to one side will see, when the subject breathes deeply, a shadow (formed against the lower wall of the depressions) descend with inspirations along the interspaces mentioned.

Absence of the diaphragmatic phenomenon can be of material significance in diagnosis only when it is unilateral, since it cannot be observed at all in a small percentage of normal subjects. Any condition which causes immobility of the diaphragm, paralysis of this muscle, or pathological changes in the abdomen or chest sufficient to prevent its descent or to prevent expansion of the inferior part of the lung, will obviously be associated with an absence of this phenomenon on the side affected, as, for instance, in pleurisy with effusion. Litten called attention to the fact that this phenomenon was absent in empyema, but present in subphrenic abscess. This phenomenon is best observed in spare subjects.

SECTION V.

PALPATION AND PERCUSSION, WITH REFERENCE TO THE LUNGS.

PALPATION FOR EXPANSION.

The expansion of corresponding regions on the two sides may be compared by palpation, although one can usually make a more accurate estimate and comparison of expansion by inspection.

When palpating for expansion of the anterior surface, the examiner should stand close behind the subject. Place in the right supraclavicular region as many, and as much of each, of the tips of the fingers of the right hand as will fit snugly in this region, the thumb resting against the vertebral column, with the left hand in a similar position on the left side. Then have the subject take several ample respirations, when the supraclavicular regions will be filled out from within by expansion of the apices of the lungs, and the examiner, by carefully adjusting the slight force he applies with his fingers, may detect any difference between the centrifugal or expanding movement of the two sides.

To compare the expansion in the infraclavicular and in the mammary regions, reach over the subject's shoulders, taking care to place the hands,

fingers together, similarly and over corresponding areas on the two sides. For the inframammary regions and lateral surfaces, reach under the arms. To palpate the expansion of the posterior surface of the chest, the examiner must stand in front of his subject.

The expansion of corresponding regions on opposite sides should be compared in the same respiratory act, because the force of different inspirations varies greatly, even when the subject tries to make them equal.

Never compare the expansion of one region on the right side with a different region on the left. Corresponding regions on the two sides should expand equally in the same respiratory act.

PALPATION FOR FREMITUS.

Normal Fremitus.—We may also palpate for surface vibration, called fremitus, which is caused by the spoken voice and called vocal fremitus, or by coughing and called tussive fremitus.

Vocal fremitus is the palpable vibration from sound waves, produced by the vocal cords while speaking. These waves or vibrations are transmitted down the column of air in the trachea and bronchi, and along the walls of the trachea and bronchi to the lung tissue and thence outwards to the surface of the chest. They are naturally greatest at the point of their origin (the larynx), and diminish in force as the distance they travel increases. They are further diminished in force

by every change in the direction of their course and by passing from a medium of one density to a medium of a different density. So that they are greatly dissipated by passage through normal lung tissue, and the vocal fremitus felt over the surface of the normal chest is much less than that felt over the larynx or trachea.

One might suppose that when palpating for vocal fremitus both of the examiner's hands should be applied to corresponding regions on the two sides simultaneously, and base their opinion upon the fact that different vocal acts of the same subject vary in force—essentially the same reasons previously given for the advisability of the simultaneous testing of the respiratory expansion of corresponding regions of the chest. This argument would apply, if in palpating for vocal fremitus we compared the force of a single vibration on one side with the force of a single vibration on the other side, as we compare single expansions on opposite sides; but we do not. When palpating vocal fremitus, we compare the thrill, or sum of innumerable vibrations of variable individual force. The surface vibration is not dependent entirely upon the force of the vocal act. The pitch of the voice is one governing factor, namely, the lower the pitch of the voice, the stronger the surface vibrations—vocal fremitus.

Other conditions being equal, when the subject monotonously repeats "one-two-three" or "ninety-nine," time after time, the palpable sum of the

resulting vibrations over any given area does not vary perceptibly, from moment to moment.

Furthermore, the tactile sense is more acute in one hand than the other in nearly every individual; being more acute in the right hand of right-handed people and in the left hand of left-handed people. Therefore the examiner should palpate for fremitus only with the hand (right or left) which possesses the finest sense of touch; placing the hand in a similar position in corresponding regions on the right and left sides alternately. The direction of the fingers must bear the same relation to the underlying bones on both sides.

Normal Variations of Vocal Fremitus.—The rule which applies to expansion, namely, that in the normal it is the same in corresponding regions on both sides, does not apply to vocal fremitus.

Vocal fremitus is considerably more forcible over the apex and upper lobe on the right than it is on the left side, and it is slightly more over the right lower lobe than it is over the left lower lobe. Many reasons have been given by various authors for the above-stated difference in the normal vocal fremitus on the two sides.

There are *four* reasons for the predominance of fremitus on the right side which are widely accepted, namely:

1. The right lung is larger than the left.

2. The right bronchus is larger and shorter than the left (see Fig. 17).

3. The right bronchus has a direction almost continuous with that of the trachea (see Fig. 17).

4. The right bronchus sends a large branch (eparterial bronchus) much more directly to the

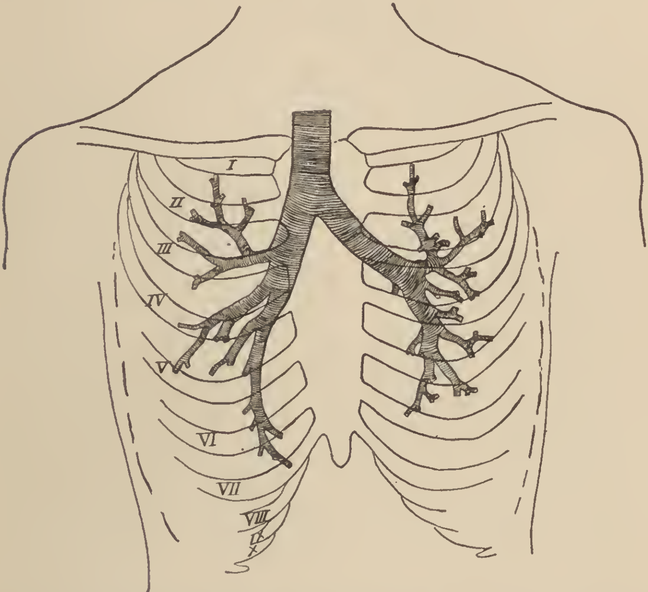

FIG. 17.—Diagram showing relations of trachea and bronchi to anterior chest wall (after Le Fevre).

apex of the lung and by a shorter route than does the left (see Fig. 17).

By the above it will be seen that a larger volume of vocal vibrations enter the right lung by a shorter route and with less deviation from their course down the trachea than the left.

Another reason for this predominance of vocal fremitus (as well as vocal resonance) over the right upper lobe will be detected by a short study of Fig. 18. This was made from a sagittal section of a frozen subject through the trachea. It there-

FIG. 18.—Relation of trachea to lungs.

fore represents the normal lateral relations. It will be noted that although the right upper lobe contained a tuberculous cavity in its outer portion, the inner half of the lobe was almost, if not quite, free from disease, and the pleura approximate to the trachea was normal. Therefore the

normal relations of the trachea to the two lungs are correctly illustrated. It will be seen that while the right upper lobe is in essentially direct contact with the trachea almost to its apex, the left upper lobe is separated from the trachea by the arch of the aorta and other less important structures. Thus, vocal vibrations pass directly from the wall of the trachea into the upper lobe on the right side, while on the left side they must, at this level, pass through and be diffused and diminished in force by the aorta. In the opinion of the author this difference in the normal anatomical relations on the two sides is the chief, if not the entire, reason for the predominance of vocal fremitus and vocal resonance over the right apex and upper lobe.

The last two reasons make it clear why the difference in normal vocal fremitus on the two sides is more marked over the apices and in the infraclavicular regions than over the lower lobes.

In the normal subject, vocal fremitus is diminished by an increase in thickness of the adipose or other tissue in the chest wall.

As has been previously referred to, a bass voice produces stronger vocal fremitus than a high-pitched voice. The louder the enunciation in a given subject, the stronger will be the vocal fremitus.

Abnormal Variations of Vocal Fremitus.—Consolidated lung tissue, as is often found in disease, allows the vocal vibrations to reach the

surface with less changes of media through which they pass than is normal. So that the vocal fremitus palpable over the consolidated area is greater than is normal for that region. Hence the statement that consolidation of the lung causes an increase in vocal fremitus.

Thickened, roughened, or adherent pleura, as is often present in disease, diminishes the vocal fremitus below the normal for the region involved.

Accumulation of fluid in the pleural sac abolishes or greatly diminishes the vocal fremitus over the fluid.

Air in the pleural sac (pneumothorax) causes absence of vocal fremitus over the air.

Complete occlusion of a large bronchus, as well as a large infarction, causes absence of vocal fremitus over the area supplied by the occluded bronchus, or over the infarction.

Loss of voice from any cause very naturally causes loss of vocal fremitus. This is not uncommon in phthisical subjects, who have a tuberculous laryngitis.

Adventitious Fremitus.—A palpable surface fremitus may be caused by some pathological obstruction to the current of air in a large bronchus and called bronchial or rhonchial fremitus, or by roughened pleural surfaces moving against one another and called friction fremitus. A grating fremitus is felt over the surface where the two rough ends or surfaces of a fractured bone rub against each other. There is a crackling fremitus

detected if we press under our fingers soft structures containing air or gas in the cellular tissue.

Note.—Palpable rigidity of the chest muscles indicative of inflammatory processes in the lung, to which Pottenger has called attention, will be left for more advanced work.

PERCUSSION.

Pulmonary Resonance.—The percussion sound elicited on the surface of the chest over a normal lung is called normal pulmonary resonance. Pulmonary resonance is the fundamental quality of all percussion sounds of the normal chest, being present to some degree in them all. It would be just as absurd to attempt to describe pulmonary resonance by words or simile as it would be to attempt a description of the color blue. Special sounds, colors, odors, and the finer and special impressions of touch cannot enter our mind nor be accurately appreciated in any way except through the special organs adapted for their reception. To know just what pulmonary resonance is, you must listen to it when produced by percussion over the lung; there is no other way.

Pulmonary resonance varies in shades of quality, intensity, pitch, and duration, with the region; because the arrangement of subjacent anatomical structures is different in the different regions. It is also different over the same region in different individuals, according to peculiarities of build, habit, amount of adipose tissue, sex, and age

(the amplitude of resonance diminishes as age advances).

The volume and degree of resonance, with a stroke of given force, is great according to the nearness of the air containing lung tissue to the surface, the amplitude of the air cells and the depth or amount of lung tissue beneath the area percussed, as well as the remoteness of large solid organs, such as the liver, the heart, or the spleen.

Resonance is greatest in the infraclavicular regions, and is obviously more marked at the height of inspiration than in any other part of the respiratory act.

With a percussion stroke of moderate force in the right mammary line, the volume or intensity of resonance diminishes and the pitch of the sound rises gradually (relative liver dullness increasing), from the fourth intercostal space downward as the arched superior and anterior surface of the liver approaches nearer and nearer the anterior chest wall. At the sixth intercostal space, where the liver comes in contact with the chest wall, resonance practically ceases, giving absolute liver dullness, except during inspiration, when the lung descends carrying pulmonary resonance an inch to an inch and a half lower down (see Fig. 19). This change in the percussion note from the fourth to the sixth intercostal space on the right side is a blending of flat quality from the liver with pulmonary reso-

nance, the former increasing and the latter decreasing in amount as we descend.

The lighter the percussion stroke along this line, the purer the resonant quality of the sound elicited, as a strong blow sets the solid liver beneath in vibration to a greater degree.

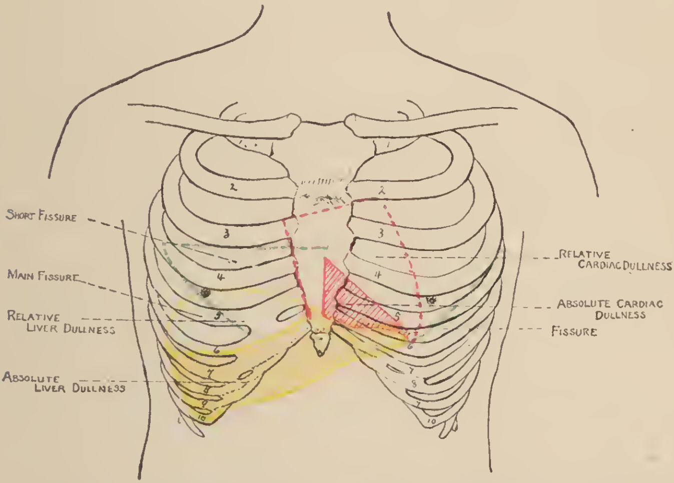

FIG. 19.—Diagram showing absolute dullness and relative dullness of liver and heart and the approximate position of interlobular fissures of the lungs anteriorly.

Relative liver dullness (only brought out on forcible percussion) extends, in the right mammary line, from the fourth intercostal space to the sixth intercostal space during expiration (see Fig. 19).

Absolute or superficial liver dullness, sometimes

called *liver flatness*, is elicited in all of the right inframammary region during expiration (see Fig. 19). It is by the position and extent of absolute liver dullness that you should learn to estimate the size and position of the liver.

NOTE.—On very light percussion over the area of absolute liver dullness in some subjects there is no appreciable resonant quality, so the note is flat.

Pulmonary resonance extends over all of the chest surface that has lung in contact with the chest wall. It is elicited behind as low as the tenth rib on both sides, and lower during extreme inspiration.

Cardiac dullness, absolute and relative (or superficial and deep), is governed and limited by the same principles of anatomical arrangement, or relations, that govern and limit liver dullness.

Absolute or superficial cardiac dullness (not flatness) is confined to a small triangle, bounded above and below approximately by lines connecting the site of the apex beat with two points in the median line—one at the level of the fourth and one at the level of the sixth costal cartilage; the median line bounding it to the right (see Fig. 19). This triangle is diminished in size during forced inspiration, from above and the left, by the distended border of the lung. It is continuous with liver dullness below. It is almost completely obliterated in cases of marked pulmonary emphysema.

Splenic dullness is only relative, and is elicited by forcible percussion over the site of the spleen (see Fig. 20).

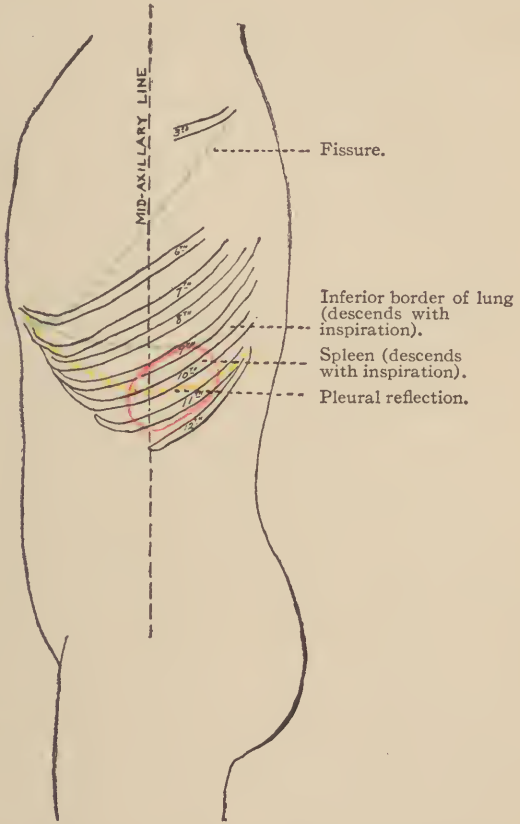

FIG. 20.—Diagram showing the position of the interlobular fissure, the inferior border of the lung, and the pleural reflection, laterally (similar on both sides), and the position of the spleen.

Tympanitic resonance is elicited over the greater pouch of the stomach when it is moderately distended with gas. This area of tympanitic resonance, sometimes called the semilunar space of Traube, is found in the lower part of the left inframammary region, anterior to the spleen and external to the left lobe of the liver. In this region tympany predominates in the note elicited, although the neighboring lung adds a pulmonary quality which modifies the note slightly.

Furthermore, the pulmonary percussion note is less resonant—more dull—according to the amount or thickness of tissue, adipose, muscle, or bone, in the chest wall over the area percussed.

Over superficial bones, as clavicles, ribs, or sternum, an osseous quality is imparted to the percussion sound, so that in pulmonary and cardiac percussion one should avoid percussing over bones when practical.

Fluid accumulations in the pleural sac give flatness or extreme dullness over the fluid, besides a sense of resistance. *This sense of resistance is an important aid to the detection of fluid in the pleural sac.*

Overdistention of the air cells, as in pulmonary emphysema, gives exaggerated pulmonary resonance, combined, as a rule, with a peculiar boxy* quality which results from the loss of elasticity of the bones of the chest.

Consolidation of lung tissue diminishes resonance

* Suggestive of the sound caused by striking an empty box.

and gives dullness in proportion to the completeness and extent of the consolidation. There is also felt a sense of resistance where the consolidation is complete and extends over a considerable area. *The sense of resistance* felt by the percussing fingers *over consolidated lung tissue is not so marked as that felt over fluid in the pleural sac.*

A thickened pleura causes dullness in proportion to the increase in thickness. A sense of resistance may be detected here, when the pleura is greatly thickened.

Consolidation of lung tissue is the only condition which diminishes pulmonary resonance (causing dullness) and exaggerates vocal fremitus over the same area. However, if the large bronchus which supplies the consolidated area is completely occluded, as occurs in some instances, the vocal fremitus will be absent, or greatly diminished. Furthermore, if the pleura is thick and adherent, or there is fluid over the consolidated area, vocal fremitus will be proportionately diminished.

Cracked-pot and the amphoric percussion sounds elicited over various kinds of cavities will be left for complete consideration in more advanced study.

SECTION VI.

AUSCULTATION WITH REFERENCE TO THE LUNGS.

THE NORMAL RESPIRATORY SOUNDS.

The normal respiratory sounds are two in number: inspiratory and expiratory, in each respiratory act. Inspiration is followed by expiration with no appreciable time intervening.

There are sixteen to nineteen respirations per minute in the normal adult when at rest.

The inspiratory sound, originating chiefly at the glottis, is caused by the inrush of air. It is carried down along the trachea, into the bronchi, and thence, after innumerable subdivisions and deflections, it enters the air vesicles with the inspired air. The tubular quality heard over the trachea and bronchi is replaced by a vesicular, breezy murmur, which is heard on the surface of the chest over the lung tissue—the normal inspiratory murmur.

The expiratory sound, originating first at the mouths of the collapsing alveoli as the expired air is forced on into the bronchioles, is augmented as the current of air gains velocity and passes on into the bronchi and trachea. It travels in a direction way from the surface of the chest, and

away from the listening ear. Except at the right apex, over primary bronchi and trachea, the normal expiratory murmur is only heard, on the chest surface, in one out of every five normal subjects, when the subject's attention is not directed to his breathing. The expiratory sound varies in duration, intensity, and quality with the individual and with the chest region.

Over the surface of the lung (except over apices and bronchi) the expiratory sound, when heard in the normal, is less intense, of shorter duration and softer in quality than the inspiratory murmur. Over the trachea in the suprasternal region it is always heard, where it is long, loud, high-pitched, harsh, and tubular in quality.

Elements of Respiratory Sounds.—In auscultation, as well as in percussion, the sounds have four elements: quality, intensity, pitch, and duration. The respiratory sounds should also bear a certain relation to each other, called *rhythm*.

Rhythm.—Over the surface of a normal chest, the expiratory sound, when audible, follows almost immediately upon the inspiratory.

Types of Breathing.—*The two fundamental types* of respiratory sounds in the normal are *bronchial* or *tubular* breathing, which is heard most intense over the trachea and less intense over primary bronchi, front or back (see Figs. 21 and 22 for these areas); and *vesicular*, or normal respiratory murmur or breathing, heard purest in the left infraclavicular region.

Bronchial or tubular breathing consists of the two respiratory sounds, inspiratory and expiratory, separated by a distinct interval of time. They both have a more or less harsh tubular quality, are of high pitch, and more intense than

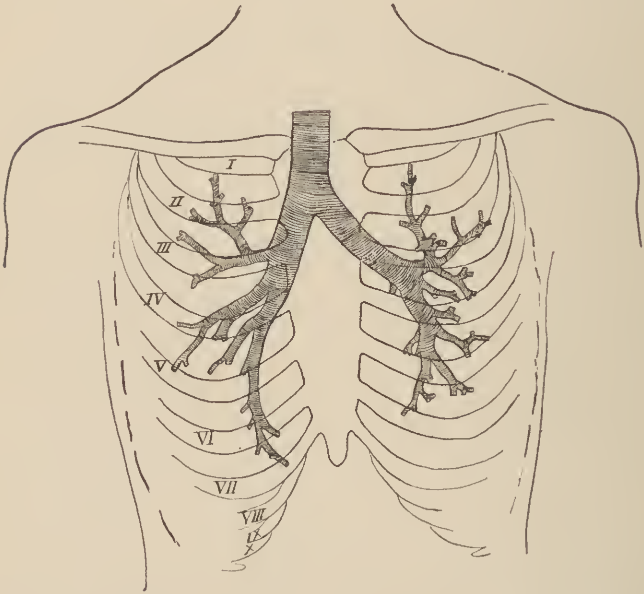

FIG. 21.—Diagram showing relations of trachea and bronchi to anterior chest wall (after Le Fevre).

vesicular breathing. Here also the duration of the expiratory sound is greater than in vesicular breathing.

Only by continued practice in listening to the respiratory sounds in the various regions will you

be able to recognize the normal for these regions, and learn how the various elements of respiratory sounds vary in different normal subjects. For instance, when the duration of the expiratory

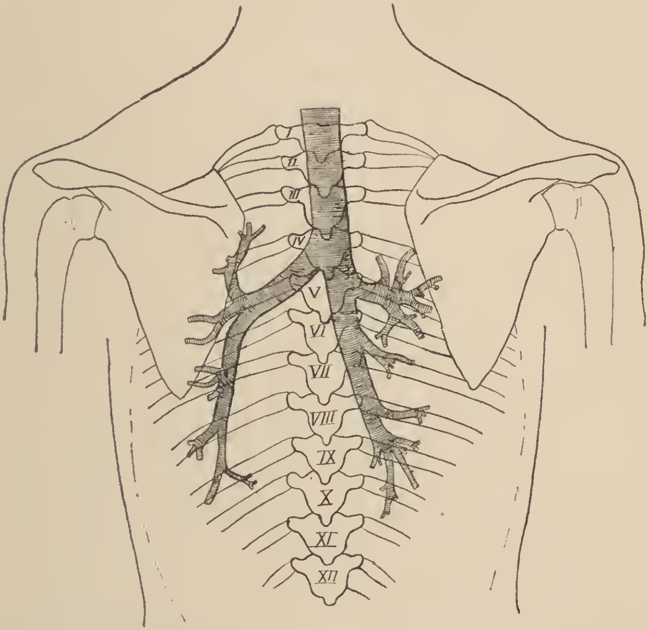

FIG. 22.—Diagram showing relations of trachea and bronchi to posterior chest wall (after Le Fevre).

sound is prolonged beyond the normal for the region given.

It is frequently the location of a type of breathing that signifies pathological change. For instance, if the type of breath sounds normally

heard directly over a primary bronchus is detected in the infrascapular region, we know that there is a change in the lung at that point (consolidation of lung tissue).

Normal Bronchovesicular Breathing.—Over the apex of the right lung, in most subjects, the respiratory murmur is normally different from that over the apex of the left lung. Over the right apex during ample respiration the breathing is a blending of the bronchial and the vesicular sounds: it is bronchovesicular. The inspiratory sound is more intense, higher in pitch, and of a harsher quality than on the left side, and the expiratory sound is more intense, higher in pitch, of a harsher quality, and longer in duration than the expiratory sound on the left side.*

ABNORMAL RESPIRATORY SOUNDS.

1. A normal sound, bronchial or bronchovesicular breathing, heard in a locality where it is not naturally located.

2. *Intensity*, exaggerated, diminished, or absent.

* The student must familiarize himself with the type of breathing normal to the right apex. It is especially marked where the chest wall is thin, and is the same as that heard over a small area of partial consolidation of lung tissue in other regions, such as occurs in the incipient stage of pulmonary tuberculosis; and since the right apex is the most frequent site of the primary involvement, in this condition, it is at once obvious that an error in diagnosis might occur readily, unless we use extreme care and keep the above in mind while examining the apices of the lungs.

3. *Rhythm* interrupted, interval between inspiratory and expiratory sounds prolonged or expiratory sound prolonged.

4. *Amphoric* (musical) and cavernous breathing.

Bronchial, or **tubular** breathing, like the sound caused by blowing through a tube, with no vesicular element, signifies complete consolidation of lung tissue (obliteration of air vesicles), unless heard over trachea or bronchi.

Bronchial breathing may be very harsh, intensely tubular, and sound as if produced very near the ear where there is a considerable area of complete consolidation, as in acute lobar pneumonia; or it may be faint and distant, as in small or central areas of consolidation. It is not the volume or nearness, but the quality (tubular) which gives this type of breathing its name and primary significance.

In proportion to the increase of the bronchial or tubular element in the respiratory sounds heard over a region is the degree and extent of the consolidation of lung tissue beneath.

Bronchovesicular breathing, called also *harsh*, or *rude*, is heard in a normal thin-walled chest in the right supra- and infraclavicular regions. It is only by prolonged study and practice that one comes to know when the bronchial element of this sound in this locality is sufficiently prominent to indicate a change in lung tissue (partial consolidation). In bronchovesicular breathing the expiratory sound is of higher pitch and longer duration than is normal for the region.

In the absence of other signs or symptoms, bronchovesicular breathing at the apices cannot be accepted as indicating disease of the lung. If this type of breathing—bronchovesicular—is heard in any other part of the chest, it signifies partial consolidation of lung tissue; that some, but not all, of the air vesicles in the area are obliterated (filled with exudate).

Exaggerated, diminished, or absent respiratory sounds obviously signify exaggerated, diminished, or absent respiratory function of the lung tissue from some cause. These conditions may be circumscribed in a small area or general over an entire side.

For instance: Respiratory sounds are exaggerated over the healthy lung when other parts of the lung or lungs are compromised by disease or injury. They are diminished over areas of interstitial infiltration in many cases of pulmonary tuberculosis. They are also diminished over areas of thickened pleura, moderate accumulations of fluid in the pleural sac and where the supplying bronchus is partially occluded. The respiratory sounds are absent over large accumulations of fluid in the pleural sac, where the supplying bronchus is completely occluded, extreme cases of thickened pleura, some cases of pneumothorax with collapsed lung, and over large solid growths within the chest or large infarctions or large pulmonary abscess.

Interrupted rhythm, called **cog-wheel** or **wavy**

breathing, is of comparatively slight significance. It is said by some authorities to be suggestive of beginning infiltration early in some cases of pulmonary tuberculosis. Prolonged interval between inspiratory and expiratory sound, as well as prolonged expiratory sound is the result of either consolidation of lung tissue, loss of elasticity of the vesicle walls or obstruction to the air current. The pitch and quality of the sound, and other physical signs enable us to determine which of these three conditions is present.

Amphoric respiratory sound has a musical quality like that produced by blowing gently into the mouth of a bottle. *Cavernous* is only less musical; both depend for origin upon a cavity of some kind communicating with a bronchial tube. The cavity must be occupied completely or partially by air. It may be formed within the lung tissue or in the pleural sac, as in pneumothorax. In the latter there is a distinctly metallic quality to the breath and voice sounds.

ADVENTITIOUS SOUNDS WHICH ARISE IN THE RESPIRATORY APPARATUS.

By the above is meant sounds which are entirely abnormal; not modifications of the normal respiratory sounds. These adventitious sounds may be râles, gurgles, pleuritic friction sounds, or splashing sounds.

Râles, gurgles, and friction sounds are caused by the normal respiratory air currents and move-

ments. They are heard with either inspiration, expiration, or with both. Splashing sounds are caused by artificial or forced shaking of the chest.

Rales may be *dry* or *moist*.

Dry Rales.—There are two kinds of dry râles: *sibilant* and *sonorous*, both of which are produced by localized narrowing of the lumen of bronchi by:

a. Tenacious mucus.
b. Swollen mucous membrane.
c. Contraction of the muscular coat.
or *d*. Pressure from without.

Sibilant râles are fine and high pitched; they arise in tubes of small calibre, or where the constriction leaves a very small opening through which the inspired and expired air can pass.

Sonorous râles are snoring and low in pitch; they arise in tubes of large calibre, or where the constriction is not so marked.

Moist rales may be large, medium, or small, and are produced by air passing through fluid or mucus in the bronchi or abnormal cavities. Usually the size of the tube in which they are produced governs the size of the râles; which are heard. *Gurgles* are the largest of moist râles; they are caused by air passing through very liquid mucus, usually in a cavity or large bronchus. The smallest moist râles are called subcrepitant, and they are produced in the bronchioles of very small calibre.

The crepitant râle is a fine high-pitched sound,

similar to the sound produced by rubbing the hair above the ear between our thumb and forefinger. This râle is heard only at the very end of inspiration. It occurs in the first stage of lobar pneumonia, and sometimes in the third stage of this disease as the "râle redux."

Here it occurs in the air vesicles which contain mucus; and the mechanism of its production is probably the sudden separation of the agglutinated walls of the air vesicles. The crepitant râle also occurs in some cases of acute pleurisy; so that it may arise either intrapleural or intrapulmonary.

Pleuritic friction sounds are produced by the movement of the two surfaces of diseased or injured pleura against each other. There are numerous kinds of friction sounds, dependent upon the character of pathological change causing them.

Splashing sounds, sometimes called "succussion," are the result of the succussion of fluid in a cavity which contains some air. They may therefore arise intrapleural, as in hydropneumothorax, intrapulmonary, as in tuberculous or large abscess cavities, or in the hollow abdominal viscera, such as the stomach or large intestine.

VOICE SOUNDS CALLED VOCAL RESONANCE.

Vocal resonance is the sound heard upon the surface of the chest when the subject speaks or whispers (the latter is called "*whispered resonance*"). Normally, its intensity or distinctness

depends upon the character or force of the voice and the region auscultated, and also varies in different individuals.

Vocal resonance in a given subject is greatest over the trachea and primary bronchi, and more intense over the right than the left apex.

The subject should repeat "one-two-three, one-two-three" and so on, or "ninety-nine" over and over several times in monotone. The student must listen to the vocal resonance in every region to learn the normal for each region. He should listen also while the subject whispers the same words, to become familiar with the normal whisper resonance in the various regions. Then listen to the resonance of cough, as changes in this sound are often of value in diagnosis.

Normal vocal resonance may be altered as follows by various disease changes:

Exaggerated or increased.
Diminished.
Distant.
Absent.

or It may be changed in quality (*i.e.*, bronchophony, pectoriloquy, amphoric or cavernous voice and egophony).

Vocal resonance is the audible analogy of vocal fremitus which is palpable; its seat of origin is the same (the vocal cords), its method and route of transmission to the surface the same, and the conditions governing the force or degree of vocal resonance heard upon the chest surface are the

same as those governing vocal fremitus. The same conditions increase or diminish both to an equal degree.

NOTE.—You should understand that both vocal fremitus and vocal resonance are greater over their point of origin (the glottis) than at any other point upon the body surface; that no change in the lung actually increases them above their original force; and that when we say they are "increased" or "exaggerated" we mean above the normal *for the region named.*

In absolute consolidation of considerable lung tissue each word may be heard distinctly upon the chest surface: this is called *bronchophony*. If the whisper is heard as distinctly, as is usually the case, it is called *whisper-bronchophony*.* *Pectoriloquy* is an advanced degree of bronchophony.

Amphoric and cavernous voice sounds occur with cavities associated with amphoric or cavernous breath sounds.

NOTE.—*Egophony* will be left for a more advanced study.

* In some cases the whisper will give more satisfactory results than the spoken voice. Bronchophony is heard in association with bronchial breathing, not with broncovesicular breathing.

SECTION VII.

THE HEART. TOPOGRAPHICAL ANATOMY, ACTION AND SOUNDS.

OUTLINES.

The Area of Absolute or Superficial Cardiac Dullness.—A small triangle, the base of which is formed by a midsternal line from the level of the upper border of the fourth costal cartilage down to the level of the lower border of the sixth costo-sternal articulation. The other sides of this triangle are lines connecting the extremities of the base line with the inner edge of the visible or palpable apex beat. It represents the portion of the anterior surface of the heart (right ventricle) which lies in contact with the chest wall and gives an almost flat note on percussion (see Fig. 23). It is important that the student learn to mark out this, the area of *absolute* or *superficial cardiac dullness* by percussion. It is by the size, shape, and position of this area of absolute dullness that we may learn whether the heart is normal in size and position by estimation.

The area of relative or deep cardiac dullness, that in which cardiac dullness is mixed with pulmonary resonance, on forcible percussion only, extends well beyond the above triangle in all directions

except downward and to the right (where it blends into liver dullness). This triangle represents the true anatomical outline of the heart, and is marked upon the surface with fair accuracy as follows:

A point over the true apex, about $3\frac{1}{2}$ inches to left of the median line in the fifth intercostal

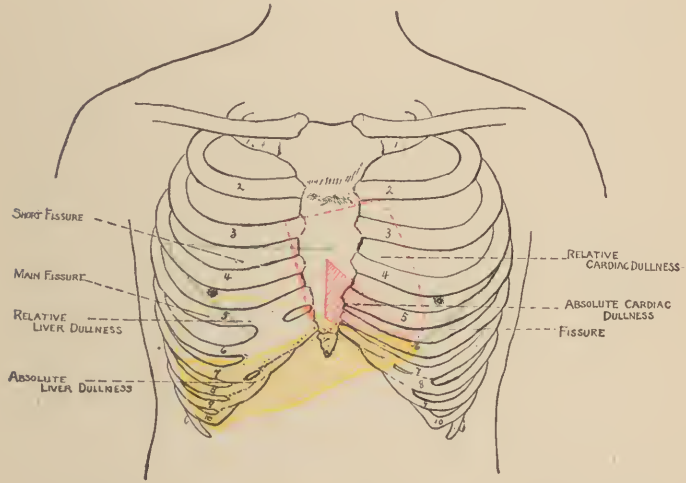

FIG. 23.—Diagram showing absolute dullness and relative dullness of liver and heart, and the approximate position of interlobular fissures of the lungs anteriorly.

space, is connected by a slightly curved line, convex to left, with a point 1 inch to left of sternum on the inferior border of the second costal cartilage (left border); a straight line connecting the latter point with a point $\frac{1}{2}$ inch to right of sternum on upper border of third costal cartilage

(upper border); a straight line from this point to the right sixth costosternal articulation (right border); then a straight line from this point to the starting-point (inferior border) (see Fig. 23).

Apex Beat.—The normal position of the apex beat is in the left fifth intercostal space, $2\frac{3}{4}$ to $3\frac{1}{2}$ inches from the median line; this coincides in the average male to a point $1\frac{1}{4}$ inches within the left nipple line in the fifth intercostal space. It is due to the striking of the lower part of the right ventricle (near its apex) against the chest wall.

The apex beat may not be visible where there is much adipose tissue, even in the normal. There are some subjects with only an average amount of adipose tissue in whom the apex beat is not visible. The beat may or may not be palpable in such cases, though it is always audible, in the normal. The apex moves an inch or two to right or left when the subject lies on his right or left side, moving more in expiration than during inspiration.

Immobility of the apex beat is strongly suggestive of some disease change, especially adhesive or obliterative pericarditis.

Displacement of the Apex Beat.—The apex may be displaced by disease or deformity, or anomalous positions of the heart, as in those rare cases of transposition of viscera, in which all of the internal viscera are usually transposed; it may also be displaced by disease of neighboring viscera or by change of the subject's position.

The true apex and left border of the heart con-

sists of left ventricle. The most superior portion of the heart is the left auricle. The extreme right portion is right auricle. The inferior border and most of the anterior surface is right ventricle.

The left ventricle and auricle lie mostly posterior

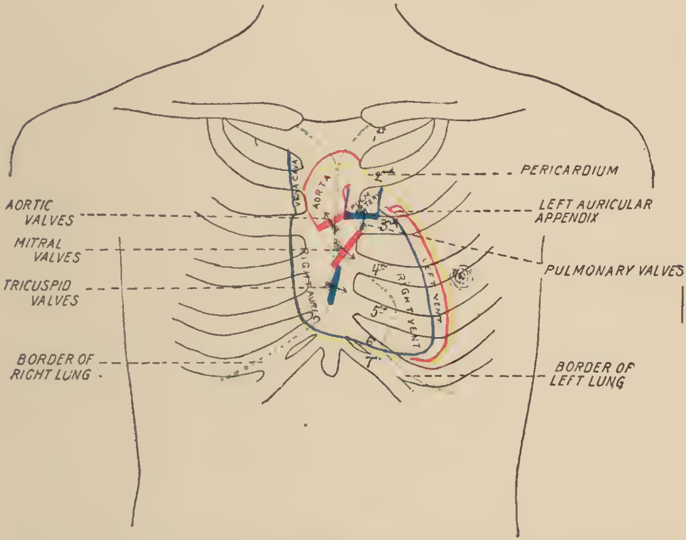

FIG. 24.—Diagram showing the position of the heart, great vessels, and valves. The borders of the lungs are indicated by green dotted lines. Note: The arrows indicate the direction of normal blood currents at the valves.

(see Fig. 24). From left ventricle to left auricle through the mitral orifice the direction is upward and backward from the apex.

From left ventricle to aorta through aortic orifice is upward and forward and to right.

From right ventricle to right auricle through tricuspid orifice is to right.

From right ventricle to pulmonary artery is upward and forward and to left.

The under surface of the heart is separated from the stomach by the diaphragm.

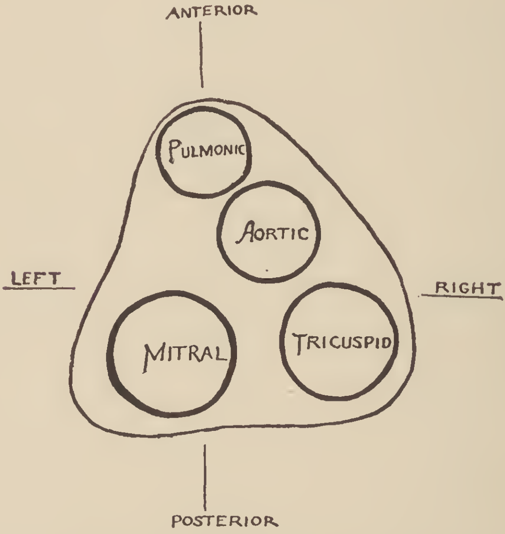

FIG. 25.—Diagram showing the horizontal relations of the orifices at the base of the heart (after Le Fevre).

Valves.—*The pulmonary, aortic, mitral, and tricuspid valves* are placed in the order given, from above downward, all behind the left half of the sternum from the level of the upper border of the third costal cartilage to the fourth intercostal space, the mitral being farthest to the left. The

pulmonary valves lie behind the third costosternal articulation (see Fig. 24).

The sites of the valves are not the points at which the sounds produced at these valves can be heard with greatest intensity.

The pericardium is reflected up to embrace the first two inches of the great vessels. The sac is conical, its base being attached to the diaphragm (see Fig. 24).

The aorta is nearest the anterior chest wall in the second intercostal space just to the right of the sternum. The transverse portion of the arch of the aorta passes from before backward and to the left above and in contact with the left primary bronchus. It reaches the side of the vertebral column just to the left of the lower border of the fourth dorsal vertebra.

NORMAL HEART ACTION.

In physical exploration of the heart, it is necessary for the student to have in his mind a clear picture of the action, shape, and position of this organ, and the direction of its blood currents as associated with the sounds and intervals between sounds (see Fig. 26).

With the first sound both ventricles contract simultaneously, the apex of the right ventricle strikes the chest wall, the mitral and tricuspid valves are closed and the aortic and pulmonary valves forced open by the blood in the ventricles. Blood rushes from the left ventricle into the aorta

DESCRIPTION OF FIG. 26.

Diagram showing the relations between the heart sounds, muscle contractions, blood currents, position of valves and apex, in one complete heart cycle. (Applies to either right or left side of heart.)

A. When the first sound is heard, ventricles contract, apex strikes the anterior chest wall, auriculo-ventricular valves close, aortic and pulmonary valves open, blood is forced into aorta and pulmonary artery, the columnæ carnæ and chordæ tendineæ are on tension and blood flows passively into auricles from the veins.

B. When the second sound is heard, aortic and pulmonary valves close, ventricles relax, blood continues to flow passively into auricles from veins, auriculo-ventricular valves begin to open, apex recedes from chest wall.

C. Aortic and pulmonary valves remain closed, auriculo-ventricular valves open, blood flows passively into ventricles from auricles and into auricles from veins.

D. Auricles contract, auriculo-ventricular valves thrown wide open, blood flows forcibly from auricles to ventricles, ventricles distended, aortic and pulmonary valves remain closed. . . . Then the cycle is repeated.

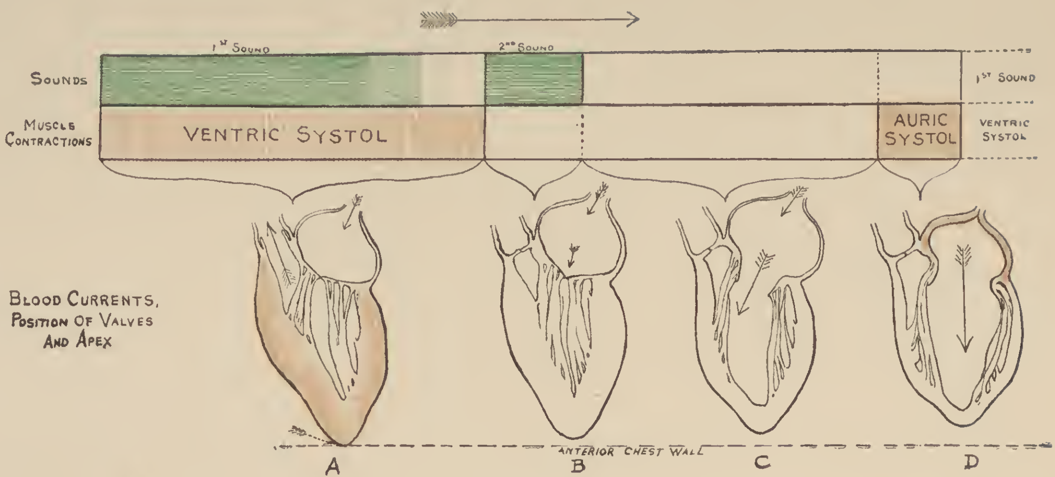
1st Sound
2nd Sound
Sounds
1st Sound
Muscle Contractions
VENTRIC SYSTOL
AURIC SYSTOL
Ventric Systol
Blood Currents, Position Of Valves And Apex
Anterior Chest Wall
A
B
C
D

FIG. 26.

and from the right ventricle into the pulmonary artery. This period is called *systole* (A, Fig. 26). Here the columnæ carnæ, and chordæ tendineæ are on tension and prevent the mitral and tricuspid valves from being forced back into the auricles.

The first sound is longer in duration, lower in pitch than the second, its termination is not so sharp and it has a different quality. It is caused by the impact of the apex against the chest wall and closure of the mitral and tricuspid valves. The contraction of the ventricle walls and the rush of blood may add elements that soften the quality of this sound. It is heard with greatest intensity at the apex and with diminishing intensity in all directions from the apex, transmitted farthest in the direction of the blood current, over the great vessels.

Following the first sound is a very short period of silence, during which the ventricles are still contracted and the auricles filling with blood from their veins, then the ventricles relax and the second sound is heard.

With the second sound the aortic and pulmonic valves snap closed by the weight of the columns of blood in aorta and pulmonary artery, and the gradually increasing amount of blood in the auricles begins to force open the mitral and tricuspid valves. There is no muscular contraction with the second sound (B, Fig. 26).

The second sound, short, sharp and high pitched, is caused by the closure of the aortic and pul-

monary valves. It is heard with greatest intensity over the third left costosternal articulation and is transmitted with diminishing intensity in all directions, especially into the great vessels and to the apex, where it is heard distinctly.

Period of Silence.—Following the second sound is a period of silence, during which the heart is passive, the blood flowing into the auricles from their veins freely, and freely but passively from the auricles into the ventricles (C, Fig. 26). The auricles and ventricles both are slowly distended during this period, called *diastole*, which is lengthened by slow heart action and shortened when the heart action is fast. The duration of systole is much less affected by changes in rapidity of heart action than is diastole.

Auricular Systole.—In the end of this period of silence, the auricles contract without causing audible sound. This contraction of the auricles is of very short duration; it forces the blood they contain into the ventricles, distending them, so the cycle is completed (D, Fig. 26); and immediately comes systole* and the first sound again.

* "Systole" or "diastole" unqualified refer to the ventricles.

SECTION VIII.

INSPECTION, PALPATION, AND PERCUSSION WITH REFERENCE TO THE HEART.

INSPECTION WITH REFERENCE TO THE HEART.

The chest and arms should be freely exposed. The subject should be examined sitting or standing, and lying down. Inspect first from in front of the subject, then step to the side away from the source of light and inspect from this position.

Venous and Arterial Pulsation.—Note the absence or presence of venous pulsation in the external jugular vein, and the degree and character of visible pulsation in the carotid and brachial, temporal and radial arteries. Also note the condition of the peripheral circulation, as shown by presence or absence of cyanosis of lips, ears, nose, fingers, or œdema of feet and legs.

Contour of Precardial Region.—Inspect closely the precardial region and note whether the contour is normal or if there is deformity, diffuse or localized, of any shape. If there is any localized bulging, (as is seen in some cases of cardiac hypertrophy in a young subject and in some cases of pericardial effusion of great amount); note whether or not it visibly pulsates, and if any part of it is retracted synchronous with the apex beat (as sometimes occurs in obliterative pericarditis).

We may observe pulsation in the fourth and third interspaces, due to retraction of the lung from disease of this structure, or extreme dilatation of the heart. Note also the absence or presence of pulsation in the epigastric region, its degree and character if present. Heaving pulsation of the epigastric region is seen in some cases of tricuspid regurgitation, where the right side of the heart is dilated.

The Apex Beat.—Observe the apex beat, its position and extent or character, whether regular or irregular or intermittent in rhythm and force of visible pulsation. The visible apex beat should be confined to an area not more than one inch in diameter. The apex beat may be displaced downward, upward, to left or right; by disease of the heart itself, pericardium, pleura, or neighboring tumor formation. When there is a large amount of fluid in the left pleural sac, the apex may be displaced to the right, even as far as the right nipple line in some cases. It is never displaced to the right by disease of the heart itself, although pulsations may be seen to right of the apex from this cause.

Have the subject lie first on his right and then on his left side and note the mobility of the visible apex beat.*

Extensive adhesions between the two pericar-

* When examining a *patient*, it is well also to employ palpation, percussion, and auscultation at this time to determine cardiac mobility; it avoids unnecessary annoyance.

dial surfaces is naturally associated with immobility of the apex.

Inspect the back of the chest and note carefully the contour along the side of the spine overlying the course of the descending thoracic aorta, to exclude or detect swelling from aneurysm of this structure.

PALPATION.

The Pulse.—The radial artery is the one best adapted to palpate in most subjects. The temporal, facial, or dorsalis pedis arteries may be palpated for the pulse. Corresponding arteries on both sides should be palpated for the pulse. If the two sides are of decidedly unequal force, there is either anomaly of the arteries, pressure upon, or disease of an artery or arterial trunk nearer the heart; as, for instance, aneurysm of the arch of the aorta is usually associated with inequality of the radial pulse on the two sides.

Method of Palpation of the Pulse.—Place the tips of three fingers upon the radial artery and the thumb on the dorsum of the wrist, thus compress the artery gently against the smooth anterior surface of the lower end of the radius.* The subject's arm and hand should rest comfortably on some surface, or his hand be held firmly by the examiner's other hand.

Palpable Elements of the Normal Pulse.—*Frequency.*—Count the pulsations. The average

* Some writers state that the examiner's index finger should be placed proximad.

is seventy-two per minute in a normal adult male when at rest; it is a little faster in women, and much faster in early childhood.

Force.—Note carefully the strength of each impulse: they should all be the same.

Rhythm.—They should follow each other with uniform intervals.

Compressibility.—The lumen of the artery should be easily obliterated, and the wall of the artery should not be palpable between beats.

Size, Duration.—Each impulse has volume or size, taking some time to rise to its full height and time to descend; it does not spring up instantaneously nor disappear abruptly when normal.

Tension.—The artery is felt partially distended between pulsations.

Dicrotism.—The dicrotic wave should not be palpable.

NOTE.—Any or all of the above may be changed by disease of heart and vessels; some of them may be altered by excitement or exercise.

Tracheal tugging, a condition which occurs where there is aneurysm of the aortic arch, is a rhythmical tug downward of the trachea, synchronous with the cardiac systole, the pulse; it may be detected in the following manner:

Have the subject throw his head well back, the chin elevated, and head resting against a firm support; then if the examiner stands behind the subject, with his thumbs applied to either side

of the inferior maxilla and gently but firmly applies his index and middle fingers to the side of the trachea, he will feel the trachea drawn quickly down with each contraction of the subject's heart. Do not mistake the pulse in your own finger tips for tracheal tugging, as one is liable to do.

Palpation of the Heart and Aorta.—Palpate the apex beat gently with the tips of one or two fingers to determine the features mentioned for inspection. Palpate the precardial area with the palm of the hand or with fingers. Palpate for the aorta in the second intercostal space just to right of sternum. Then palpate for the aortic arch with one finger pressed down into the episternal notch, while the subject inclines head forward. The thoracic aorta is not usually palpable unless displaced or dilated from disease. Palpate the epigastric region for pulsation.

If any local bulging is observed, palpate to learn if it is hard or soft or fluctuates or whether it pulsates, and, if so, whether the pulsation is expansile with the cardiac systole.* Also note if it is enlarged by cough or crepitates under digital pressure, due to air or gas within it, and whether it is tender or not (whether manipulation causes pain).

PERCUSSION.

The aorta normally does not alter perceptibly the percussion note along its course. If aneurysm of

* As occurs in a palpable aneurysm.

the aorta exists, it will give dullness to a degree and extent in proportion to the size of the tumor.

The Heart (Area of Absolute Dullness or Flatness).—Here the finger (pleximeter) should be placed parallel with the sternum at some distance from the borders of the heart, and *light* percussion

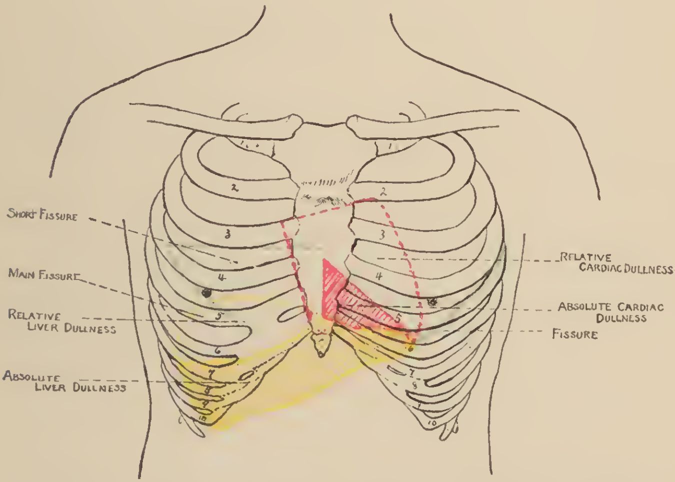

FIG. 27.—Diagram showing absolute dullness and relative dullness of liver and heart, and the approximate position of interlobular fissures of the lungs—anteriorly.

applied, with one or two fingers as plessor, then the finger (pleximeter) moved in toward the center of the cardiac area until the pulmonary resonance is replaced by absolute dullness. The area should be mapped out above and on both sides, below it merges into liver flatness toward the median line.

This area indicates that portion of the heart which is not covered by lung tissue. In the normal, with the subject erect or supine, it is limited above by an oblique line from the left fourth costosternal articulation to the apex beat, on the right by the median line and below by a horizontal line through the apex beat (see Fig. 27). Although it is diminished by pulmonary emphysema and by extreme inspiration, it is comparatively easy to map out by percussion, and in most cases it is more reliable to estimate the size and position of the heart from this than by the area of relative dullness.

The area of absolute cardiac dullness may be changed in position, shape, or size (increased or diminished) by disease of the heart, pericardium, or neighboring viscera.

SECTION IX.

AUSCULTATION WITH REFERENCE TO THE HEART AND BLOOD VESSELS.

The stethoscope should be employed in auscultation of the heart.

The subject should be standing, sitting, or lying flat on his back.

THE HEART SOUNDS.

If the stethoscope is placed over the site of the apex beat, two sounds are heard: one, the first, synchronous with the apex beat, is the loudest, lowest in pitch, softest in quality, slightly rumbling and longest in duration. After a very short period of silence, the short, sharp second sound is heard, followed by a longer period of silence. If the stethoscope is moved, say one inch at a time, toward the base of the heart, the first sound becomes less intense as the second sound grows more intense, until at the third left costosternal articulation, where the second sound is heard with greatest intensity.

The student should listen to these sounds over the whole pericardium and over the aorta, in the second right intercostal space, until he is familiar with their character in every region as well as

their duration and rhythm. Listen especially at the four points of greatest importance:

Valve Sound Areas.—The areas on the surface of the chest where the sounds, or elements of sounds, originating at the respective valves are heard with greatest intensity. They are as fol-

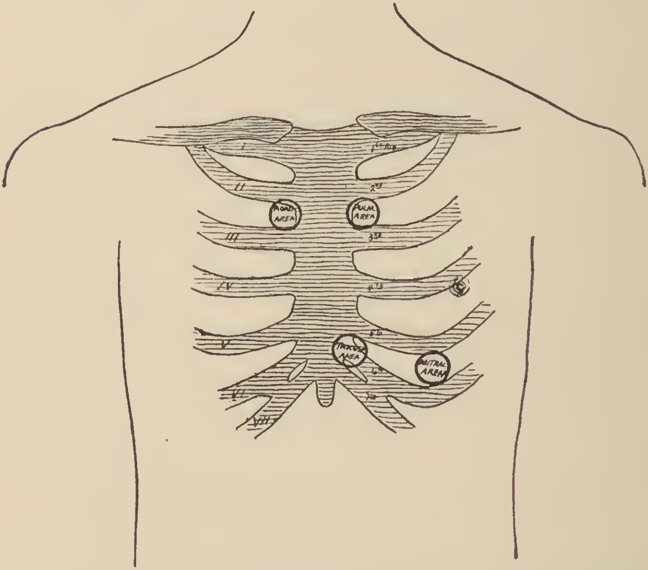

FIG. 28.—Surface areas where the different valve elements predominate in heart sounds.

lows: Fig. 28.—1. The apex, which is the surface center of sound originating at the mitral valve—the mitral area.

2. The second right intercostal space close to the sternum—the aortic area.

3. The second left intercostal space close to the sternum—the pulmonary area.

4. The left sixth costosternal articulation—the tricuspid area.

These are not the anatomical locations of the several valves (see Fig. 29), but are approximately the surface centers of sounds orignating at the respective valves named.

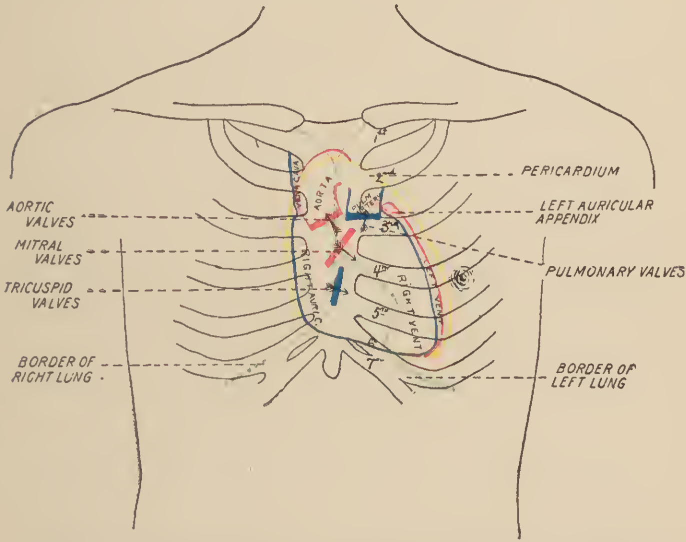

FIG. 29.—Diagram showing the position of the heart, great vessels, and valves. The borders of the lungs are indicated by green dotted lines. Note: The arrows indicate the direction of normal blood currents at the valves.

Modification of Heart Sounds by Exercise.—The heart sounds are more intense and higher in pitch immediately after vigorous exercise of any kind, because the tension of its walls is increased by temporary engorgement with blood.

Cardiac sounds may be modified in *rhythm*, *intensity* or by the occurrence of *adventitious sounds*, *murmurs*.

Rhythm may be modified as follows: *Intermittent*, *irregular*, *gallop rhythm*, *reduplication*, and some other varieties of restricted significance.

Not uncommonly, some of the ventricle contractions are not of sufficient force to cause a palpable pulsation in the radial artery and give an erroneous impression of intermittent or abnormally slow heart action.

Intensity.—Both or either one of the heart sounds may be increased or diminished in intensity by disease. Normally they are heard more intense in individuals with thin chest walls, and less intense where the chest wall is thick and contains much adipose tissue.

ADVENTITIOUS SOUNDS.

Murmurs are sounds which accompany or replace the normal heart sounds. They may be pericardial or endocardial.

Pericardial murmurs are caused by roughening of the pericardial surfaces from disease. They occur synchronously with the heart movements, are confined to part or all of the precardial area, are usually of a rubbing quality, and may be single or double. They are most intense during expiration and are increased if the subject leans forward. The usual point of maximum intensity is the left

fourth costosternal articulation, and they are not transmitted beyond the limits of the pericardium.

Endocardial murmurs may be *hæmic*, *valvular*, or *congenital*.

Hæmic murmurs, caused by changes in the blood, are systolic in time, accompany and follow the first sound, are soft in quality, heard over the body of the heart or the great vessels, transmitted in the direction of the normal blood current and often of greatest intensity over carotid arteries. They may be associated with a venous hum heard over the external jugular veins and are not associated with change in the size and position of the heart unless other disease coexists.

Valvular murmurs are caused by obstructed or abnormal currents of blood as a result of roughening or deformity of the valves or orifices from disease.

NOTE.—*Congenital murmurs*, which are caused by congenital deformity of the heart or the great vessels, will not be discussed in this work.

In order to determine the seat and gross method of origin or cause of a murmur, we must observe three points:

(1) Its rhythm (relation to the normal cardiac sounds, time).

(2) The point where it is heard with maximum intensity, and

(3) The direction in which it is best transmitted.

Rhythm.—In isolating a murmur, we must first make sure which is the first and which the second

DESCRIPTION OF FIG. 30.

Diagram showing the relations between the heart sounds, muscle contractions, blood currents, position of valves and apex, in one complete heart cycle. (Applies to either right or left side of heart.)

A. When the first sound is heard, ventricles contract, apex strikes the anterior chest wall, auriculo-ventricular valves close, aortic and pulmonary valves open, blood is forced into aorta and pulmonary artery, the columnæ carnæ and chordeæ tendinæ are on tenson and blood flows passively into auricles from the veins.

B. When the second sound is heard, aortic and pulmonary valves close, ventricles relax, blood continues to flow passively into auricles from veins, auriculo-ventricular valves begin to open, apex recedes from chest wall.

C. Aortic and pulmonary valves remain closed, auriculo-ventricular valves open, blood flows passively into ventricles from auricles and into auricles from veins.

D. Auricles contract, auriculo-ventricular valves thrown wide open, blood flows forcibly from auricles to ventricles, ventricles distended, aortic and pulmonary valves remain closed. . . . Then the cycle is repeated.

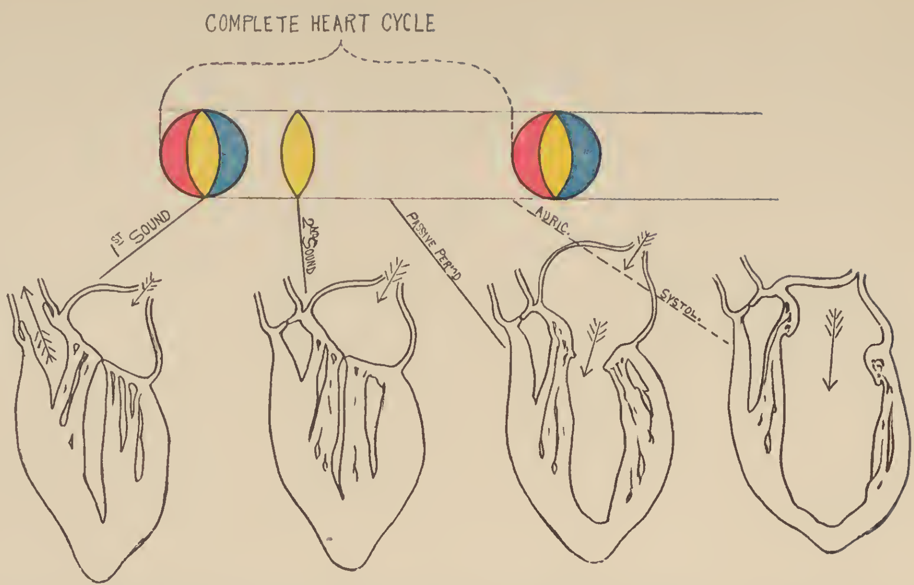

FIG. 30.—Graphic illustration of heart sounds and action: Red, muscular element; orange, valvular element; bluc, impact of right ventricle against chcst wall.

sound. This is not always easy in a diseased heart, and it is well to run the stethoscope by degrees from apex to base and back to apex, moving it an inch or less at a time, watching the visible apex beat closely all the while. It is obvious that we must first be sure with which sound the murmur is associated. Here also the student must at once acquire the habit of carrying in his mind a clear picture of the normal relation of the heart action and the direction of the blood currents to the normal sounds throughout auscultation (Fig. 30).

Murmurs may be caused by a blood current passing through an orifice in the normal direction (direct) or by a current which leaks backward (a regurgitant current) from a ventricle to an auricle or from the aorta or pulmonary artery to a ventricle (indirect). In either case the murmur will either immediately precede, accompany and follow, or entirely replace one of the normal heart sounds.

The points of maximum intensity of the several murmurs are the points on the surface to which the vibrations are conducted with least resistance.

The direction of transmission of every murmur is always with the current of blood which produces it, whether normal in direction or regurgitant, (direct or indirect).

NOTE.—A *systolic puff* is occasionally heard over the subclavian artery, and is usually of little or no diagnostic significance; it usually accompanies either inspiration or expiration, and is rarely persistent throughout both. Such a puff is occasionally a result of distortion of the arterial calibre by adhesive

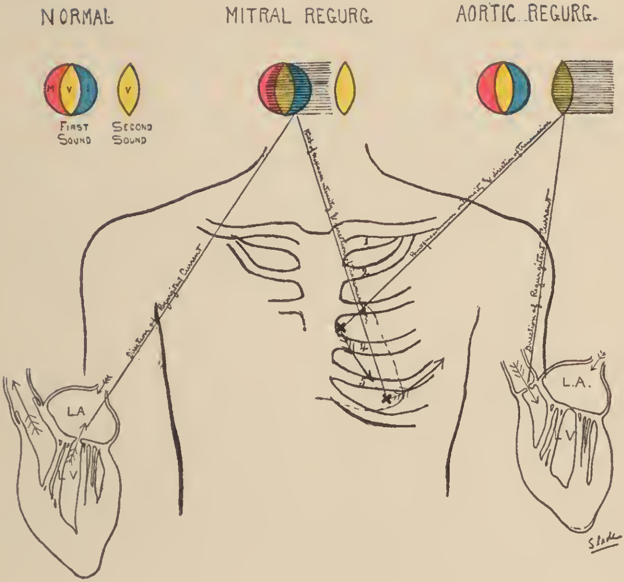

FIG. 31.—Normal heart sounds and graphic illustration of cardiac murmurs, regurgitant, left side: *M*, Muscular element; *V*, valvular element; *I*, impact of right ventricle against chest wall.

bands resulting from tuberculous or other disease at the apex of the pleura.

PRACTICAL EXERCISE, TO BE COMPARED WITH A NORMAL SUBJECT.

Mitral Regurgitant Murmur (Fig. 31):

Rhythm accompanies and follows the first sound (systolic).

Point of maximum intensity: the apex.

Direction of transmission: upward to the left, toward the axilla.

Heard posteriorly, in the left interscapular region, over the fifth rib.

Aortic Regurgitant Murmur (Fig. 31):

Rhythm accompanies and follows the second sound or replacing it (diastolic).

Point of maximum intensity: third left intercostal space at the border of the sternum.

Direction of transmission: downward along the left border of the sternum.

Heard at apex.

Mitral Obstructive Murmur, Direct (Fig. 32):

Rhythm: immediately preceding, and ending abruptly with, the first sound (presystolic).

Point of maximum intensity: the apex.

Direction of transmission: confined to the region of the apex.

Palpable thrill: it is this murmur (mitral obstructive) which is often associated with a presystolic thrill, palpable over the apex.

Aortic Obstructive Murmur, Direct (Fig. 32):

Rhythm accompanies and follows the first sound (systolic).

Point of maximum intensity: right second intercostal space at the border of the sternum.

Direction of transmission: upward into the great vessels.

Right side murmurs corresponding to the above are differentiated from them by their points of maximum intensity and the directions in which

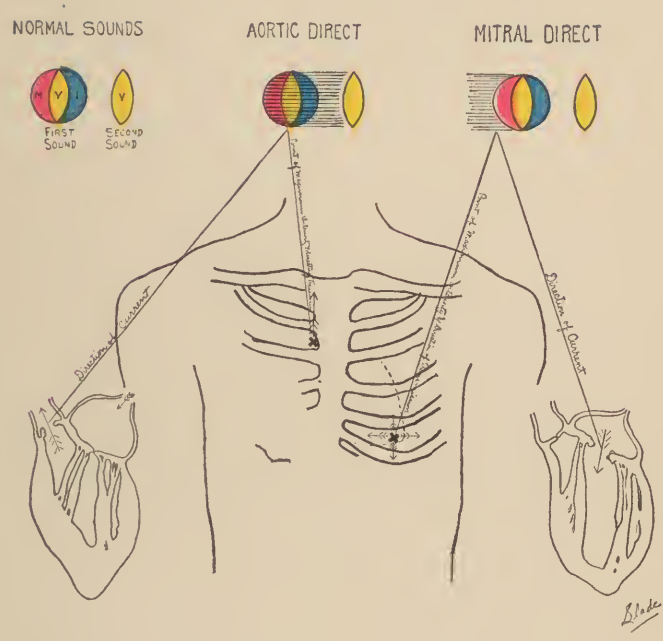

FIG. 32.—Direct cardiac murmurs, left side: *M*, Muscular element; *V*, valvular element; *I*, impact of right ventricle against chest wall.

they are transmitted. The rhythm is obviously the same on the two sides (Fig. 33).

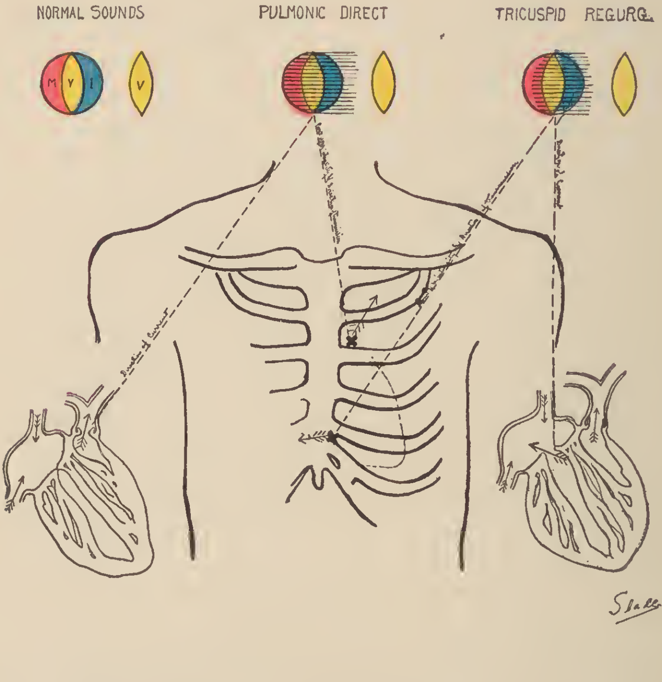

FIG. 33.—Right side murmurs: *M*, Muscular element; *V*, valvular element; *I*, impact of right ventricle against chest wall.

SECTION X.

THE ABDOMEN. TOPOGRAPHICAL ANATOMY AND GENERAL RULES GOVERNING PHYSICAL EXAMINATION OF THE ABDOMEN.

ABDOMINAL LANDMARKS.

Fixed Landmarks	The xiphoid cartilage, Tip of the ninth costal cartilage, Inferior border of the tenth costal cartilage, Chest of the ilium, highest point, Anterior superior spine of the ilium, Poupart's ligament, Symphisis pubis.
Movable Landmarks	Umbilicus, External border of rectus muscle.

Lines.

Besides the Median Line:

Horizontal Lines	1. Subcostal line, through inferior border of the tenth costal cartilage. 2. Intertubercular, through highest point of crest of ilium.	
Vertical Lines	1. Right Poupart line 2. Left Poupart line	Through the middle of Poupart's ligament.

Regions.—The surface of the abdomen is thus divided into nine *regions*, namely, from above downward:

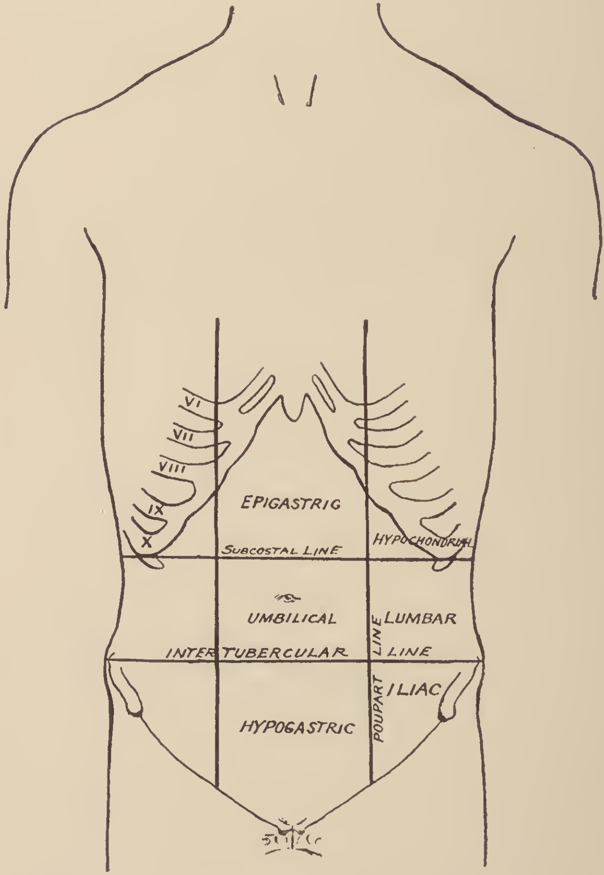

FIG. 34.—Regions of abdomen (after Le Fevre).

Centrally—1 epigastric, 1 umbilical, and 1 hypogastric.

Laterally—2 hypochondriac, 2 lumbar, 2 iliac (see Fig. 34).

TABLE OF UNDERLYING CONTENTS OF REGIONS OF THE ABDOMEN.

Right Hypochondriac	*Epigastric*	*Left Hypochondriac*
The liver. The gall-bladder. The hepatic flexure of the colon. The right kidney.	The stomach. The liver. The transverse colon. The omentum. The pancreas. The duodenum. Both kidneys and suprarenal capsules. The cœliac axis. The aorta. The posterior extremity of the spleen. Lymph nodes.	The spleen. The stomach. The pancreas. The splenic flexure of the colon. The left kidney. The left extremity of the liver.
Right Lumbar	*Umbilical*	*Left Umbilical*
The ascending colon. The right kidney. The small intestine.	The transverse colon. The omentum. The duodenum. The small intestine. Right kidney (left kidney occasionally). The aorta. Lymph nodes.	The descending colon. The omentum. The left kidney (occasionally). The small intestine.
Right Inguinal (or Iliac)	*Hypogastric*	*Left Inguinal (or Iliac)*
The cæcum (the origin of the appendix is behind the right Poupart line).	The small intestine. The sigmoid flexure (the bladder in children or if greatly distended, and the uterus in pregnancy). The cæcum. Lymph nodes.	The sigmoid flexure.

SURFACE MARKINGS

of Some Viscera or Parts of Viscera of Special Importance in Physical Exploration.

Cardiac Orifice of Stomach.—Seventh costo-sternal articulation, left side.

Pylorus.—Just to right of median line, 1 1/4 inches above the subcostal line.*

Inferior Border of Stomach.—About 1 inch above the subcostal line (it is lower when distended).

Inferior Border of Liver.—Approximately a line from the lower extremity of the right costal margin to a point 1 inch below the left nipple.

Gall Bladder.—Where Poupart's line crosses the right costal margin (*i.e.*, the angle formed by the outer border of the rectus muscle and the free border of the ribs. Also near the tip of the ninth rib, right side).

The Spleen.—Between the ninth and twelfth ribs—left side, parallel with the tenth rib. It does not project beyond the costal margin.

Kidneys.—The epigastric region contains most of both, deep, against the posterior abdominal wall. The right kidney is the lower and projects slightly into the umbilical region; the left to, or a little below the subcostal line.

Head of the Pancreas.—Just to the right of the median line and just above the subcostal line.

The Duodenum.—Beginning at the pylorus,

* Many *x*-ray photographs of the stomach containing bismuth show the pylorus displaced downward. Sometimes it is found on a level even below the umbilicus. This is not normal.

it embraces the head of the pancreas to right and below, ending nearly an inch above the subcostal line just to left of the median line; its lowest or

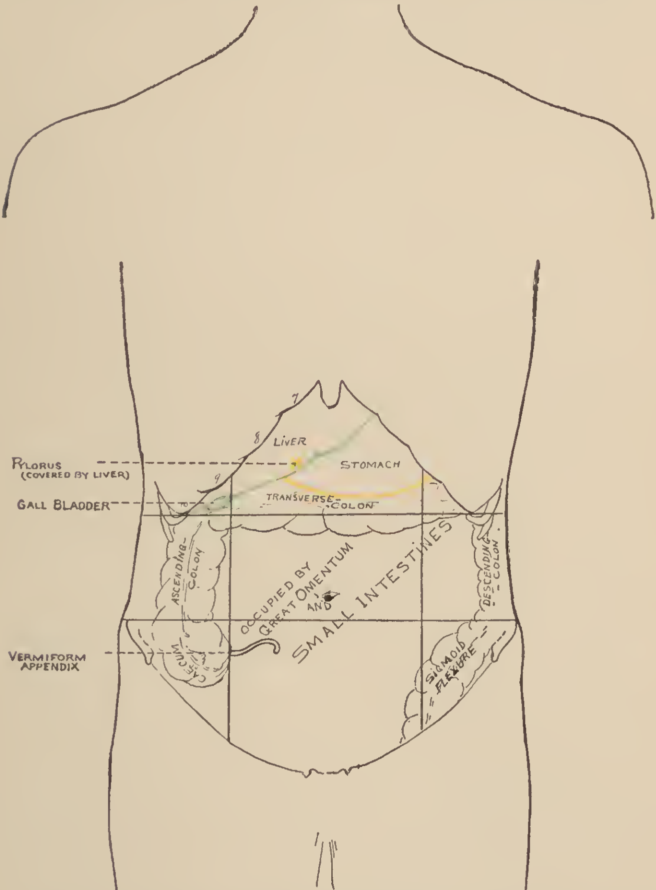

FIG. 35.—Diagram showing the position of the superficial abdominal viscera and the vermiform appendix.

middle section lying in the extreme upper portion of the umbilical region.

The Cæcum.—Chiefly in the right iliac region.

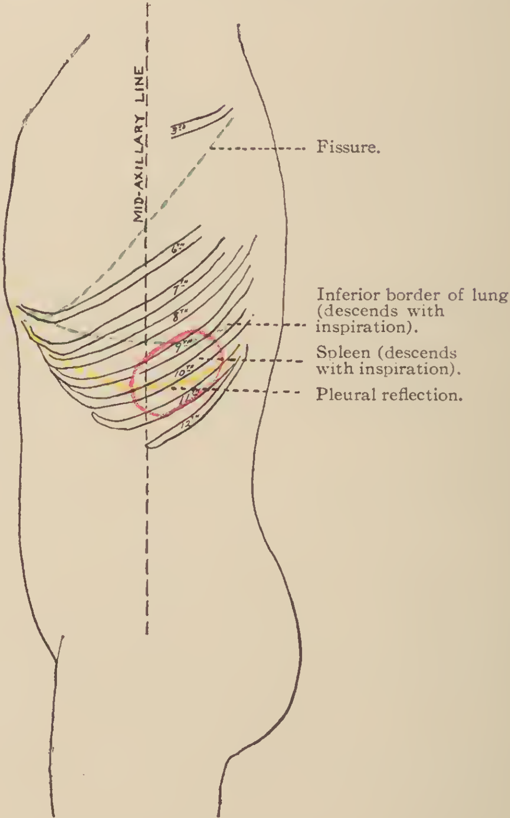

Fig. 36.—Diagram showing the position of the interlobular fissure, the inferior border of the lung, and the pleural reflection, laterally (similar in both sides), and the position of the spleen.

Base of the Appendix.—On the right Poupart line, 1 1/4 inches below the intertubercular line (*i.e.*, the mid-point in a straight line connecting the anterior superior spine of the ilium with the umbilicus in the average abdomen.

The Cœliac Axis.—About the centre of the epigastric region.

The Bifurcation of the Abdominal Aorta.—About the centre of the umbilical region.

INSPECTION OF THE ABDOMEN.

On inspection the normal abdomen varies greatly in contour with the individual—sex, age, and amount of adipose tissue being important factor which control the normal contour within the limits of health. The position of the subject controls the contour especially in those with loose or fat abdominal walls. The general and detail contours of the normal can only be learned by practical observation. When the average subject reclines upon his back, the contour in the erect posture is fairly well maintained, but in those with loose, flabby, and fat abdominal walls, the centre of the abdomen is flattened and the sides bulge.

The umbilicus in the average subject occupies nearly the centre of the umbilical region, but falls much lower in those with loose, flabby abdominal walls.

The borders of the recti muscles are only visible in those with moderate or little adipose tissue; the prominence of these muscles in health is usually

in proportion to the general muscular development of the subject. They will stand out more prominently if we ask the subject to try to raise his chest up from the surface upon which he lies, while his lower extremities are held extended.

The respiratory movements of the abdomen must be observed. The upper portion of the abdomen should rise and fall evenly with respirations, more in men than women. Although the liver, stomach, and spleen descend with inspirations, their change of position cannot be seen in the normal subject.

The pulsations of the abdominal aorta may be seen when the abdominal walls are very thin and flabby.

PALPATION OF THE ABDOMEN.

The subject should lie upon his back, his thighs flexed, and he should breathe naturally. In the normal subject, palpation is negative; none of the abdominal viscera is palpable in health, except the abdominal aorta, which may be palpated; its pulsations being very easily felt in thin subjects with flabby abdominal walls, where it is occasionally mistaken for abdominal aneurism.

The pelvic organs are palpable by vaginai or rectal examination only.

PERCUSSION OF THE ABDOMEN.

The subject should lie upon his back. The liver, spleen, stomach when distended with gas,

the urinary bladder when distended, and the gravid uterus are the only abdominal organs which can be mapped out by percussion in the normal subject.

To percuss for the spleen the subject must lie on his right side if recumbent.

Auscultation reveals nothing in the average normal abdomen.

SECTION XI.

SPECIFIC RULES GOVERNING PHYSICAL EXAMINATION OF THE ABDOMEN.

INSPECTION.

Contour.—Note whether normal or distended; its shape if distended, whether dome-like (due to

FIG. 37.—Normal abdomen. Note the subcostal depression and muscle outlines.

FIG. 38.—Abdomen distended by gas. Note the dome shape.

gas) (see Fig. 38), or flat centrally with bulging sides (due to fluid or fat flabby walls) (see Fig. 37); whether the rectus muscle is more prominent on one side than the other as occurs in localized peritonitis and is so commonly observed in cases of appendicitis.

Superficial veins, if prominent, which group,

the central (due to obstruction to portal vein) or the lateral (due to obstruction to the vena cava), or both (due to obstruction of the vena cava and portal vein), as seen in some abdominal tumors and where there is a great accumulation of fluid in the peritoneal cavity (ascites).

The umbilicus, whether depressed or protruding, with a cluster of distended veins about it—caput medusæ (seen in portal obstruction).

Note whether there is any localized prominence, mass, or protrusion at any point and, if so, whether it moves with respiration. Tumors of liver, spleen

Fig. 39.—Abdomen distended by fluid in the peritoneal cavity. Note flattened top and bulging sides.

and stomach, and other loosely attached tumors in the upper part of the abdomen may descend with inspiration.

Whether there is any visible pulsation, its site and charcter, if observed.

Intestinal Peristalsis.—Is intestinal peristalsis

visible? If so, in what regions and to what degree? Note carefully the direction and limits of the movements. This may help determine the presence and location of intestinal obstruction in some cases. Are the lower intercostal spaces and costal margin equally prominent on the two sides? (Liver abscess may render the right hepatic area prominent, causing the lower intercostal space to bulge.)

PALPATION.

Be sure your hand is not cold. Lay your hand on gently and first compare the muscle tonicity or rigidity on both sides (especially of the recti muscles); they should be equal. Then with gentle pressure search the entire surface for any abnormal mass or resistance. Then apply moderate pressure with the two fingers or thumb in the nine regions to learn the absence or presence of undue tenderness (the epigastric region may be slightly tender without the presence of disease).

Then palpate for abnormal mobility or enlargement of liver, spleen, and kidneys. For the liver and spleen, place the fingers of one hand evenly about two inches below the costal margin in the proper region, press first backward and then upward beneath the costal border during expiration. Then the subject should take a deep breath while the pressure is applied; this forces the liver and spleen downward, but they must be enlarged or displaced to be felt.

In palpating for some deep structures, such as kidneys or spleen, or deep abdominal tumors, considerable pressure is required. In such instances, lay the hand on lightly and increase the pressure very gradually. Where great force is needed, the tactile sense of the palpating fingers will remain more acute if the required pressure is applied by superimposing the fingers of the free hand upon the palpating fingers.

I give here a method of palpating an enlarged or depressed liver, when the abdominal walls are tense from fluid or gaseous distention of the abdomen, which has proven of service to me in some cases.

In the condition mentioned, when the anterior surface of the liver is smooth and its lower portion thin, the usual method—pressing the fingers in more or less gradually—will reveal nothing in most instances, because the lower portion of the liver, that portion below the costal margin, recedes so easily. This is specially true when the liver floats in ascitic fluid. The steadily increasing resistance of the overstretched abdominal parietes as we increase our pressure, renders the sense of touch in the palpating fingers less acute.

In such a case, if we lay the tips of the fingers on the surface, below the free border of the ribs, without pressure, and suddenly jab them in with moderate force, the impact with the surface of the liver is felt distinctly (Fig. 40); the liver recedes promptly; but by repeating the above over various neighboring places, we easily determine the margin

of the liver. The fingers must be raised completely between each jab, to allow the liver and abdominal wall to resume their former relations.

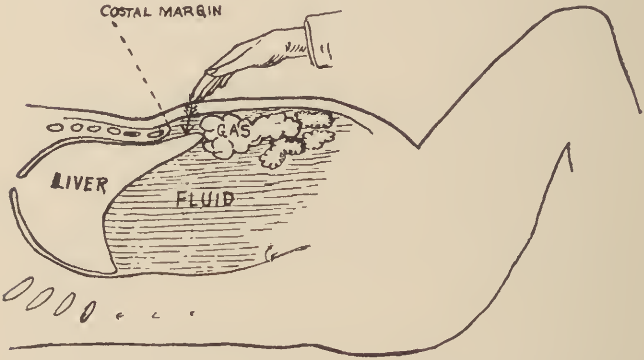

FIG. 40.—To palpate the liver; one quick jab in direction of arrow.

This same method may be applied to the palpation of other solid and movable abdominal organs or tumors.

To palpate for the kidneys, stand on the side palpated; place the left hand behind, just below the ribs and press forcibly forward, with the right hand in front at the upper boundary of the lumbar region; press moderately under the costal margin and have the subject take a deep breath. If the kidney is movable or enlarged, it may be felt to descend with inspiration, but in most cases it is more distinctly felt, as it glides up from under the fingers, with expiration. The right kidney is more often palpable than the left; neither is palpable when absolutely normal.

Then palpate carefully any abnormal mass, if one is detected, to determine its size, shape, mobility (with respiration or by your hand), and character, also to which abdominal organ it is attached or is part of. Note whether hard or soft, smooth, rough, nodular, or furrowed; whether it fluctuates or pulsates with the heart beat; if it pulsates grasp it cautiously to learn whether the pulsation is expansile (suggesting aneurysm) or only projectile. New growths and inflammatory masses may be any shape, although the shape of a mass may be significant; for instance, a sausage-shaped mass suggests intussusception.

Surface Veins.—*If the surface veins* are distended, we should apply digital pressure to them in order to make sure the direction of their flow; this will help to determine the site of the obstruction causing their distention.

Abdominal Distention.—*If there is abdominal distention*, palpate to detect absence or presence of fluid in the peritoneal cavity,* with the subject on his back. Apply the palm of one hand to the side of the abdomen in the lumbar region and tap the opposite side with the fingers of the other hand several successive blows. If there is fluid, a wave is felt by the hand that rests on the opposite wall, as a quivering impact following each succeeding blow.

To avoid confusion by a wave which may be transmitted across a fat abdominal wall, a third hand should be pressed gently (by an assistant); its ulnar side applied vertically in the median line.

* Ascites.

PERCUSSION.

With alternating strong and light percussion strokes percuss down the entire length of the abdomen, in the median line and on either side, noting the variation of sounds elicited; there should be various degrees of tympany in all parts. The tympany is more marked where the viscera are distended with gas and the note duller according to the absence of gas beneath.

Keep in mind the anatomical position and limits of the several viscera as you proceed.

Then, by percussion, mark the limits of the solid viscera, liver and spleen and any masses detected (by dullness present in an unusual position). A large solid organ or mass (solid or fluid) in apposition to the abdominal wall, as well as fluid in the peritoneal cavity, yields a flat note on percussion.

A small mass or organ yields a dull or dull tympanitic note.

The stomach and intestine when they contain gas yield a tympanitic note.

A mass covered by gas containing viscera yields a dull note on strong or forcible percussion. A light stroke over the same area yields a tympanitic note.

Forcible percussion over the spleen yields dull resonance, called dullness. Percussion of the spleen is not satisfactory in many cases, because this organ lies between the resonant lung without and tympanitic stomach within.

The distended bladder and the **gravid uterus** give a flat note on percussion over them.

The pancreas and kidneys do not affect the percussion note when normal. When the kidney is greatly enlarged, a path of tympany may be elicited over it along the course of the colon. This is not the case where the spleen is enlarged, as it is in contact with the abdominal wall throughout.

Gas free in the abdominal cavity yields a tympanitic note over the entire surface; tympany supplanting the usual liver dullness. (This is observed in most cases where there is perforation of the intestine.)

As the fundamental quality of all percussion sounds of the normal chest is pulmonary resonance, so is tympany the fundamental quality of all percussion sounds of the normal abdomen. This quality, tympany, is normally present in all abdominal percussion sounds, in varying degrees; in some localities the tympanitic element being very slight, for instance over the liver where it can scarcely be detected at all, especially when the colon and stomach contain little or no gas.

Over the stomach, cæcum, ascending and descending colon, we usually elicit the greatest degree of tympany in the normal abdomen.

AUSCULTATION.

Auscultation is not usually applied in the routine physical exploration of the abdomen.

Over an abdominal aneurysm we may detect the sounds characteristic of this condition (aneurysmal bruit). In rare instances peritoneal friction sounds are heard over intra-abdominal growths.

We may listen to detect the sounds caused by abnormal movement of intestinal gas, which occurs in some pathological conditions, which will not be considered herein.

In pregnancy the fœtal heart beats may be heard and counted by the eighteenth or twentieth week of pregnancy.

The uterine bruit, a blowing sound synchronous with the maternal pulse, may be heard by the fourth month of pregnancy.

Hæmic murmurs may be heard over the abdominal aorta in anæmic subjects with thin abdominal walls, and should not be mistaken for aneurysmal bruit, which exists when aneurysm of the abdominal aorta is present.

In some cases of peritonitis a friction rub is heard, with respiratory and forced movements.

Finally, it must be said that no routine physical examination is complete without searching for spinal tenderness by pressure upon the vertebræ. Examination of the lower extremities by inspection and palpation for skin changes, condition of superficial veins, the arteries, joints, muscles, and tendon reflexes. It is also advisable to inspect the external genitals and anus, and palpate for lymph-nodes above and below Poupart's ligament on both sides.

SECTION XII

BLOOD-PRESSURE AND THE SPHYGMOMANOMETER

The term blood-pressure, through custom and usage, has come to mean arterial pressure, usually that of the brachial or radial arteries, vessels which are convenient for estimations. Measurements, however, have been made for other arteries, as well as for capillaries and veins, the greatest pressure being found in the large arteries near the heart, as the carotid, less in the medium sized, as the radial, much less in the capillaries, while in the large veins of the neck the pressure may be negative.

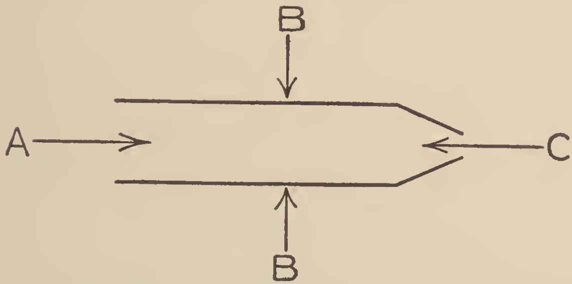

FIG. 41.—Where A represents the output of the heart per minute; B, the elastic recoil of the arterial wall, and C, the opposition to the arterial flow. The combined effect of these forces produces the arterial pressure.

Arterial Pressure.—In its practical application the arterial pressure is the one that is almost exclusively used. In simple terms, an artery may be likened to a piece of elastic rubber tubing and the forces concerned in producing the pressure may be diagrammatically represented thus:

ANALYSIS OF FORCES

A. **Output of Heart.**—It is readily apparent that the amount of blood per minute that is being sent into an artery and the force with which it is driven are important factors in causing the pressure. The output depends upon (1) the amount of blood available for each contraction of the ventricle; (2) on the ventricular rate; (3) the capacity of the ventricle; and (4) on the force of its contractions.

1. *Amount of Blood.*—The amount of blood that is returned to the left ventricle depends on various factors, among which are the rate of the return flow in the veins, which, in turn, is dependent upon the degree of patency of the arterioles and capillaries; upon the rate of blood-flow through the lungs; upon the presence or absence of obstruction at the mitral valve; and upon the presence or absence of the auricular systole (it is absent in auricular fibrillation).

NOTE.—For a full description the reader is referred to works on physiology.

2. *Rate of the Heart.—Other things being equal,* a heart beating at the rate of 90 per minute will propel more blood into the arteries than one beating at 60 per minute; in other words, will have a greater output per minute.

3. *Capacity of the Left Ventricle.*—The more blood the ventricle holds, the more will it be able to expel. The blood-pressure in the male is slightly higher than in the female, and one of the factors is the greater capacity of the ventricle in the male. In aortic regurgitation, where the capacity of the ventricle is materially increased (the expelling force is also increased) we find the arterial pressure markedly raised.

4. *Force of Ventricular Contractions.*—The more forceful the contraction, the greater will be the pressure. In strong, athletic men, due to more forceful contractions, the arterial pressure is found to be slightly above the average. It was seen above that in aortic regurgitation, with hypertrophy of the left ventricle, there was an increase of pressure partly due to more forceful contractions. In that condition of irregular heart known as auricular fibrillation some of the ventricular contractions are so weak that the force is insufficient to open the aortic valves.

B. **The Elastic Recoil of the Arterial Wall.**—In the walls of the arteries, especially in the larger ones, in contradistinction to the veins, there is a considerable amount of elastic tissue, which when stretched will recoil, and within cer-

tain limits the greater the stretching, the greater the recoil. The artery is most stretched, of course, when most filled, which is just at the end of systole, so that during diastole this force of elastic recoil is available for propelling the blood, acting as an adjunct to the heart. It is to be remembered that the function of the arterial pressure is the carrying of blood to all the tissues, and supplying their needs, and when this is satisfactorily done the circulation is said to be efficient. If for some reason the elastic recoil of the arteries were impaired, an increase of pressure would be necessary to maintain the circulation as efficient. In old age the elasticity of the arterial wall is impaired, and an increase of pressure (within limits) ensues, which is to be regarded as compensatory.

C. **The forces, represented in the diagram by C, oppose the arterial flow, and consist of** (1) **the peripheral resistance (denoted in the diagram by narrowing of the tube) and** (2) **the viscosity of the blood.**

1. *Peripheral Resistance.*—This is an important factor in the production of arterial pressure, and there is some difference of opinion whether the retardation of the flow occurs in the arterioles or in the capillaries. Starling holds that it is very largely in the arterioles. Some recent views tend to the belief that the capillary resistance may play quite an important rôle. Probably both factors are concerned.

The arterioles have nerve connection with the vasomotor center in the medulla, and their condition of constriction is regulated through the center. The mechanism of capillary constriction (whether central or automatic) is not definitely determined. Carbon dioxid and lactic acid, the result of metabolic processes, cause ready dilatation of the capillaries.

2. *Viscosity of the Blood.*—The higher the viscosity, the more friction will be offered in the passage of the blood through the arterioles and capillaries, and hence a greater resistance to the flow. Carbonic acid increases and oxygenation diminishes the viscosity of the blood.

The resultant of these various forces, described above, is the arterial blood-pressure.

Relationship of Forces.—It was previously pointed out that in advanced years there is a lessening or impairment of the elasticity of the arterial wall, but this is a very gradual process over a period of years, so that from week to week there is no appreciable difference. Therefore for practical considerations the elastic recoil of the artery may be regarded as a constant. However, the other factors concerned in the maintenance of arterial pressure are subject to ready change, and it would be natural to conclude that with so many variables involved, the resultant (pressure) would be anything but fixed and uniform. There is, however, a regulating mechanism, so that when any force becomes un-

duly active in raising the pressure, counter-influences are brought to bear with a lowering effect, and thus the pressure is more or less stabilized. It is to be pointed out that fluctuations of pressure, within limits, do occur which are physiologic and not indicative of disease.

Effect of Exercise on Pressure.—A brief examination of the sequence of events induced by exercise will disclose the interaction of the various forces and the manner of stabilizing the pressure. During quiet periods the amount of blood flowing to the left ventricle does not quite fill it to capacity, so that the output for each contraction is not the maximum. The mental attention, in preparing for exercise, as awaiting the word "go" in a foot-race, initiates the change. This mental process, through reflex action, stimulates the adrenal secretion, which causes splanchnic constriction, and a greater return flow to the ventricle with capacity filling. When the amount of returning blood becomes greater than will fill the ventricle, there follows a rise of pressure in the great veins next the heart. This reflexly, by inhibiting the vagus and stimulating the sympathetic, will quicken the heart-beat. The cardiac output is thus increased in two ways, viz., by a larger output at each contraction and by an increase in the number of contractions per minute. Increased output causes a rise of arterial pressure. As a result of exercise there is produced in the muscles carbonic acid and lactic acid, which, as we have

seen, cause a dilatation of the arterioles and capillaries, with a lowering of the pressure. The arterial blood, during exercise, is somewhat better oxygenated than during repose, reducing the viscosity and thus lowering the pressure. Thus we see that forces are brought to bear which are mutually corrective, and tend to stabilize the pressure. During exercise we find that the pressure is first raised, that later it begins to fall, and that after the exercise it may reach a point below the starting-point, depending somewhat on the severity and duration of the exercise.

NOTE.—For a full description the works on physiology must be consulted.

Systolic and Diastolic Pressures.—The pressure in the aorta is highest immediately following systole, when the ventricular contraction has driven a volume (about 60 c.c.) of blood into the aorta. This is known as the systolic pressure. There is then a gradual fall, the minimum being reached at the end of diastole. This is known as the diastolic pressure. The difference between the systolic and diastolic is spoken of as the pulse pressure. Measurements of blood-pressure usually include both systolic and diastolic readings.

Measurements of Blood-pressure.—The simplest way of estimating the arterial pressure is with the finger. The radial artery is compressed with the tip of the index-finger against the radius until pulsation ceases. The amount of force

required to obliterate the pulse can be gauged, and constant practice will educate the palpating finger until tolerably accurate estimations may be made. It is, however, difficult to convey to another any accurate quantitative idea by this method. Care must be taken to exclude any reflux wave from the palmar arch. Pressure made distally by another finger will prevent this.

Instruments.—The first measurements with an instrument were made by inserting a cannula into an artery, and connecting the cannula with a mercury manometer. This was done largely in animals and occasionally in man just before the amputation of a limb. The measurements are absolutely accurate, but the method, of course, is clinically impracticable. von Basch, using a bulb instrument on one femoral of a dog, and the cannula method on the other, made simultaneous readings and found they coincided, and thus was the first to introduce a practical sphygmomanometer.

Bulb Sphygmomanometer.—von Basch's instrument consists of a small rubber bulb filled with air and connected by tubing with a manometer (either mercurial or aneroid). The rubber bulb is placed over an artery (most easily the radial) and pressure is made on the bulb until pulsation in the artery is obliterated. The pressure communicated to the manometer is then read off. Numerous modifications of this instrument have been made. von Basch's, however,

will serve as a type of instrument for compressing single arteries. For accurate results extreme care must be used in applying the bulb instrument.

Band Sphygmomanometer.—With the band type (the one used almost exclusively in this country) a limb is compressed, the upper arm usually being selected. The band or armlet consists of a flat rubber bag covered with canvas or some unyielding substance, and connected with a bulb or small metal air pump, with which it may be inflated, and also with a manometer, which may be mercurial or aneroid. A valve is placed conveniently close to the air pump, so that air may be allowed to escape very gradually, and the pressure in the armlet regulated with accuracy. The armlet should be not less than 12 cm. in width. In taking the pressure the patient should be comfortably seated and reassured, as anxiety in nervous individuals may elevate the pressure. The armlet is then applied snugly to the arm above the elbow, and the pressure in the armlet gradually raised until the radial pulse is obliterated. The height of the mercury column is read off in millimeters and the blood-pressure in the brachial artery is expressed in millimeters of mercury.

Auscultatory Method.—In the above method the closure of the brachial artery (systolic pressure) was denoted by the absence of the radial pulse at the wrist. In the auscultatory method a stethoscope or phonendoscope is placed just

below the armlet and the pressure gradually raised as before.

As the pressure is raised there will come a place at which a faint sound is heard, and as the

FIG. 42.—Auscultatory method of determining blood-pressure.

pressure is increased the sound becomes louder, until, with still more pressure, the sound ceases. The upper limit at which the sound disappears corresponds with the systolic pressure; the lower limit, approximately with the diastolic.

NOTE.—The sound heard below the armlet is not uniform, but passes through successive changes as the pressure is altered. These changes comprise five phases: 1. The appearance of a clear sound (thud) which lasts for a fall of about 14 mm. of mercury. 2. The sound becomes longer in duration with the quality of a murmur, and persists for a fall of about 20 mm. 3. The murmur quality is lost, and a louder sound is heard, over a further fall of 25 mm. 4. Marked muffling of sounds over a fall of 5 to 6 mm. 5. The disappearance of the sound. Some observers take the beginning of the fourth phase as the equivalent of the diastolic level; others, the end of the fourth phase. In some cases the distinction between the third and fourth phases is not evident, and the beginning of the silence is then used. In aortic regurgitation the fourth phase may be continued down to 5 or 0 mm. of mercury pressure, and then the beginning of the fourth phase must be used.

Measurement of Diastolic Pressure by Oscillations.—It was stated previously that the systolic pressure was the highest pressure in the artery immediately following the cardiac systole, and that the diastolic was the minimum pressure at the end of diastole. There is; therefore, a rise and fall alternately of pressure, which may be noted in the mercury column, and since the diastolic is the minimum pressure, it will be denoted when the oscillations are greatest. Any pressure above the diastolic would lessen the extent of the oscillations. Instruments have been devised by which the oscillations can be graphically recorded and measured, and the pressure noted for maximum oscillations.

In a general way the systolic pressure depends upon the cardiac output and the diastolic upon

the degree of contraction of the arterioles and capillaries. They are, however, in a measure mutually dependent.

Normal Systolic Pressure.—There is no fixed standard for the normal pressure, but within limits, for various ages, certain approximations have been made. The pressure varies, too, with the weight of the individual, increasing with the weight.

The greatest amount of collected data has been furnished by the life insurance companies, and some of their results are here given in table form:

Systolic

Age.	Low.	High.	Average.
15–20 years	114	131	123.5
20–30 "	117	131	124.5
30–40 "	118	132	125
40–50 "	120	135	130
50–60 and over	126	140	135

These statistics are for presumably healthy persons. Life insurance examiners regard with suspicion a systolic pressure of 140 mm. in a person under forty years of age, and 145 at any age is held to be pathologic. While these findings cannot be ignored, the medical profession is disposed to consider the limits for health, set by the insurance experts, as too rigid and restricted.

Several formulæ for estimating blood-pressure have been advanced, as (1) the age plus 100; (2) 120 mm. being the normal pressure for a person

of 20; 1 mm. is added for each year (others say 1 mm. for each two years).

As previously stated, there are numerous influences, some but poorly understood, that may affect one or other of the forces concerned in the maintenance of blood-pressure, so that it seems unwise to too definitely fix the limits of physiologic systolic pressure.

Lauder-Brunton says that in advanced years pressures of 150 or higher are met with in apparent health.

Normal Diastolic Pressure.—In healthy individuals, at least, the diastolic pressure varies much, as does the systolic, and for various age periods has a proportionate increase. What was said concerning the limiting too narrowly the systolic pressure is equally applicable to the diastolic. A diastolic pressure of 95 mm. is regarded unfavorably by the insurance examiners.

TABLE OF DIASTOLIC PRESSURES

(Compiled by Insurance Examiners)

Age.	Low.	High.	Average.
15–20 years	75	84	79
20–30 "	77	86	81
30–40 "	79	88	83
40–50 "	80	89	85
50–60 and over	82	90	87

High Blood-pressure. — Reference has been made to the effect of exercise upon the pressure. Emotions of various kinds, especially anger and fear, elevate the pressure.

NOTE.—Emotions, particularly anger and fear, often initiate violent exercise, and so the pressure is already being raised before the exercise begins.

In old age there is a raising of the pressure, and, as was pointed out, within limits, it is compensatory. The pathologic conditions prominently associated with arterial hypertension are chronic Bright's disease and arterial sclerosis. Two somewhat opposed views relating to the heightened pressure may be briefly summarized. The first is that a poison (metabolic or otherwise) acting on the vasomotor center causes a constriction of the arterioles and capillaries, and there ensues a rise of blood-pressure. The arterioles and capillaries (and finally the arteries) thus subjected to pressure, undergo a thickening of their muscular coat, which, in turn, causes a further rise of pressure, and thus a vicious circle is established. A second view is that the thickening of the arterioles is primary, and that these thickened arterioles, by obstructing the arterial flow, produce a hypertension which, in turn, causes further thickening. It is a matter for future investigations to determine.

Cerebral compression, as in apoplexy, causes a rise in pressure.

Low Pressure.—A lowering of the blood-pressure is met with in shock and syncope; after hemorrhage, and following exhausting diseases, as typhoid and influenza. Low pressure is found early in pulmonary tuberculosis, and in tuber-

culosis of the adrenals (Addison's disease) exceedingly low pressures are common. Excessive use of tobacco (in small amounts it may cause an elevation) is sometimes associated with low blood-pressure. A condition met with chiefly in women, in which asthenia, visceroptosis, and low blood-pressure are associated, is not infrequent.

In cardiac disease, when dilatation occurs, a drop in pressure frequently ensues. However, when cardiac decompensation occurs without dilatation, there may occur an elevation (asphyxial rise) of the pressure.

Occasionally low pressures (90 to 100 systolic) are seen in healthy persons.

NOTE.—For a full consideration of high and low pressures the reader is referred to more complete works.

Pulse Pressure.—The difference between the systolic and diastolic pressures is known as the pulse pressure. This is not an actual force, but merely the relationship of two forces—in a sense the relationship of the strength of the heart to the resistance to be overcome. A mathematical ratio commonly given for expressing this relationship is 3:2:1—denoting the systolic, diastolic, and pulse pressures respectively. A systolic pressure of 120 mm., a diastolic of 80 mm., and a pulse pressure of 40 mm. represent the above ratio. It is frequently found, however, that this 3:2:1 ratio is not maintained, and attempts

have been made to deduce the condition of the heart and peripheral circulation from the disordered ratios, it being held that a large pulse pressure indicated a strong heart, and a low pressure a weak one. However, it is readily apparent that a long diastolic period (slow heart) allowing a more complete emptying of the arteries into the veins will be associated with a low diastolic pressure, and, in consequence, with a greater pulse pressure. Conversely, a rapid heart will have a small pulse pressure. Other variable factors are concerned and deductions from pulse pressure variations are to be drawn with considerable reserve. At most they are to be regarded as general indications.

The condition most prominently associated with a large pulse pressure is that of aortic regurgitation. In this condition the cavity of the left ventricle is enlarged, *i.e.*, its capacity is increased, and its walls are hypertrophied, and hence its expelling power is enhanced. In consequence, a greater quantity of blood is driven with increased force into the aorta, both factors combining to raise the systolic pressure. During diastole, however, a reflux leak of pressure is permitted to escape back into the ventricle through the incompetent valves (some blood flows back also), and so there is a marked and rapid fall in the diastolic pressure. A high systolic with a low diastolic and a large pulse pressure are thus characteristic of aortic regurgitation.

Conversely, aortic obstruction will have a small pulse pressure.

Venous Blood-pressure.—If the hand be allowed to hang at the side it will be noted that the veins become filled and prominent. If the arm now be raised the veins will become less prominent and the level at which they empty can be noted. Normally this occurs about the level of the third rib. The greater the venous pressure, the higher must the arm be raised.

Instrumental Measurements.—A ready way is by applying the armlet of a sphygmomanometer over a superficial vein of the arm. The armlet is inflated until the flow in the vein is stopped. The portion of the vein proximal to the cuff is then emptied with a finger. The pressure in the armlet is gradually relaxed, and when blood begins to flow again in the vein the pressure in the manometer is noted.

NOTE.—Instruments for giving greater accuracy have been devised and the student is referred to works on the subject.

Capillary Pressure.—Several methods of estimating capillary pressure have been devised. A brief description is here given of that used by Danzer and Hooker.

An air chamber, with a glass roof, and a floor made of gold-beater's skin, is connected by tubing with an air bulb and also with a mercury manometer. Screw devices for bringing the floor of the pressure capsule into contact with the

finger are used. Air is now forced into the capsule, the floor of gold-beater's skin becoming more convex, and so exerts pressure on the finger-nail.

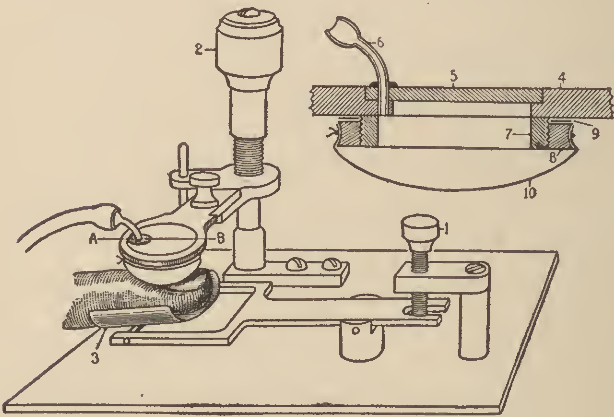

FIG. 43.—The microcapillary tonometer.

When the flow in the capillaries is stopped, as visualized through a microscope (magnifying about 70 diameters) the pressure is read off on the manometer.

The average capillary pressure is 18 to 22 mm. of mercury. The clinical application of venous and capillary pressures is, as yet, limited.

INDEX